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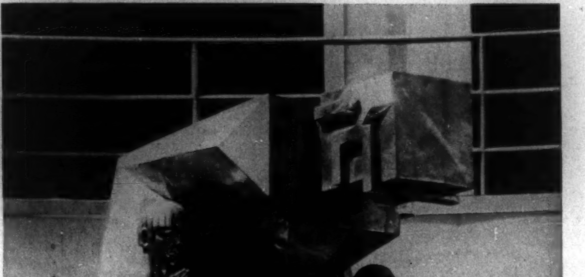

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Another Group of Institute Officers

The group of national officers newly elected for the year 1933–34 was presented in this space in the July 1933 issue. Here is presented part of the group of officers whose terms hold over from the preceding year; the remainder is scheduled for presentation in the September issue.

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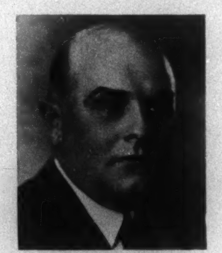

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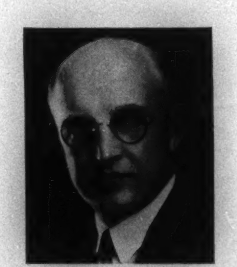

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This Month—

Front Cover

This symbolic statue in the circular courtyard at the northern entrance to the Hall of Science at A Century of Progress Exposition represents the technological sciences, in the form of the popularized version of the "mechanical man," lending a sustaining, guiding hand to mankind in his groping advance.

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Officers and Committees (For complete listing see p. 678–81, September 1931 issue of ELECTRICAL ENGINEERING)

TO KEEP the voltage regulation of a low voltage a-c distribution system as nearly constant as possible, certain optimum ratios of circuit resistance to reactance are desirable. *p. 554–8*

CABLES connected directly to overhead electric power transmission lines, especially short cables connected to high voltage lines, often are not self-protecting against impulse voltages. In such cases, protective equipment may be necessary to insure that the cable will not be a weak link in the system. *p. 559–64*

FOR the engineer without much special training in handling stability problems, a simple and accurate method of calculating the power limit of a transmission system has been developed; calculation forms and a specific example are given. *p. 569–72*

QUOTING from the 1933 report of the A.I.E.E. committee on power generation (see ELECTRICAL ENGINEERING, July 1933, p. 488–503) "some engineers believe that the future will witness an increasing number of such plants (regenerative hydroelectric plants) in the United States." An analysis of hydro-regeneration and factors limiting its application is presented in this issue. *p. 547–50*

SUCCESSFUL application of the results of laboratory illumination studies depends upon an understanding of the fundamental principles of lighting and seeing. *p. 543–6*

MACHINES have been charged with the responsibility for most, if not all, of man's social, industrial, spiritual, and aesthetic shortcomings. According to a well known educator, however, "machines, products of man's mind and skill, are also the agents by which his mind and body are set free." *p. 532–5*

METERING of symmetrical components has been treated to some extent in previous publications. Certain facts concerning power and energy metering networks are established more clearly, however, by analyzing in detail the networks for metering the different components of voltage and current. *p. 536–43*

INDUCTIVE COORDINATION, a subject of mutual interest to the electric power and communication industries, involves many phases of electrical engineering. A knowledge and appreciation of the factors involved are necessary for a proper analysis of the problem. *p. 551–4*

VARIOUS matters of importance to the Institute were considered at the regular meeting of the board of directors held in Chicago during the summer convention. *p. 577–8*

TO DETERMINE the best frequencies for use at various times of the day in short wave radio communication to South America, a year's survey was conducted. No seasonal variations were observed. *p. 529–31*

ACTIVE discussion attested to the general interest of the technical papers presented during the 6 technical sessions of the Institute's 1933 summer convention. A résumé of some of the discussions appears in this issue. *p. 578–81*

ENGINEERING FOUNDATION was urged to undertake engineering studies of broad social and economic import, at a joint meeting of the boards of directors of 4 national engineering societies, and of the United Engineering Trustees, Inc. *p. 584–5*

AMONG noteworthy features of the Institute's 49th annual summer convention were the many joint meetings of the several engineering and scientific societies holding conventions in Chicago during Engineers' Week, and Engineers' Day at the Century of Progress Exposition. *p. 573–5*

UTILIZATION in Baltimore of electric energy from the Safe Harbor (Pa.) hydroelectric plant required careful engineering study; several changes in the Baltimore distribution system were found desirable, one of which was a change in system frequency from $62^{1}/_{2}$ to 60 cycles. *p. 564–9*

AT THE annual conference of officers, delegates, and members, held during the Institute's 1933 summer convention, Dr. J. B. Whitehead, newly elected president of the A.I.E.E. emphatically expressed the point of view that the life and well being of the Institute rests with the Institute membership. *p. 576–7*

EXPERIENCE of the engineer in industrial economics has been said to give him an advantage in the broader field of political economy. If he is to venture into that broader field, however, with the idea of applying his long tried scientific methods, he should take stock of the limitations of those methods. *p. 526–8*

A Message From the President

To Members of the Institute—

My first official word must be one of appreciation of the high honor conferred upon me, and of my deep sense of the responsibility attaching to the office of president of the Institute. I pledge my constant and devoted effort for the maintenance of its best traditions.

In a time of unprecedented restriction of engineering enterprise, amid acute unemployment and consequent distress, let us take courage and cheer in the realization that the high purposes, ideals, and standards of the Institute are a precious and permanent heritage independent, in large measure, of the alternate fluctuations of industrial prosperity or depression. These ideals and standards are inherent in the quality of the products of Institute activities, and so ultimately in the aspirations, the efforts, and the loyalty of the individual member. With this loyalty assured we need have no fear, and may rest secure that the Institute will move forward in the paths well laid in its illustrious past, not only serving its members as it may, but also holding aloft for them the standard of high professional aspiration without which they can have no enduring or useful professional life.

John Boswell Whitehead
A.I.E.E. president 1933–34

The times, nevertheless, are bringing us most serious problems. The quantity and to some extent the quality of the concrete services of the Institute to its members are directly related to the material welfare of the latter. Resignations, non-payment of dues, and other diminished income, must be met by economies and a restricted volume of services if the budget is to be balanced, as it must be. Fortunately the restrictions so indicated are so far not too serious. We have in a measure spoiled ourselves in the past in the luxuries of publications, and provisions for our technical meetings. Modifications and curtailments already in force have been accepted in the finest spirit, and others under consideration are possible without serious sacrifice of the essentials of complete distribution and thorough discussion of our technical output. The remarkable outpouring of new technical material of the last few years, embracing all branches of the art, and marking its continued advance, so far is undiminished. It must and will be made available to the membership expeditiously and in convenient form. How to do this at reduced cost is one serious problem. Another is that of increasing our membership. Withdrawals recently have exceeded accessions. This tendency must be checked. Enthusiastic and promising young members should not be lost permanently because of temporary unemployment. Wavering members must be strengthened. New members must be sought. The solution to this vital problem lies in an increased activity of local membership committees stimulated by the sympathetic cooperation and support of the Institute's board of directors.

Relying on the loyalty and enthusiasm of each member, on his participation in all meetings, on his cooperation and tolerance in necessary measures of economy, and on his efforts in maintaining and increasing our members, I look forward to a stimulating year of mutual effort for useful service, and the maintenance of the Institute's distinguished record of the past.

J. B. Whitehead

The Engineering Economist of the Future

By DEXTER S. KIMBALL Cornell Univ., Ithaca, N. Y.

The engineer who aspires to solve modern economic problems by applying his well tried scientific methods, should take thought of the limitations of those methods; he must expect to do an unusual amount of studying before he can hope to replace old economic theories with others better suited to present conditions; and because of the capricious nature of the many variables involved, he should not attempt to predict future trends on the basis of past experience.

TO THE ENGINEER trained in the explicit solution of problems, basing such solutions on fairly well known facts and experiences, the wide divergence of opinion among statesmen and economists on so many economic problems now before us certainly is cause for wonder, if not amazement. It does not seem possible that, after so many years of study of economics on the part of so many able men and with the vast literature on this subject now available, there should be such violent disagreement among economists on such matters as inflation, the gold standard, and numerous others related to present conditions, the discussion of which now fills the land with raucous debate.

During the past year or more the writer as a member of a committee of the American Engineering Council has read essays by persons in many walks of life, including many professional economists all offering explanations of our present industrial predicament, and many offering solutions of existing troubles. The general impression obtained from such an experience is that practically all of these literary efforts are based largely upon *opinion* and little upon proved *principles;* and while in the aggregate they contain much wisdom and many good suggestions, they do not either collectively or individually present a clear picture of the problem, to say nothing of a definite solution. One is moved, therefore, to ponder the character of economic thought, and the place that science and engineering may and should occupy in that field.

WHAT IS ECONOMICS?

An authoritative encyclopedia defines economics as "the science that investigates the conditions and laws affecting the production, distribution, and consumption of wealth or the material means of satisfying human desires; political economy." Viewing our present uncertain condition it might well be doubted that economics is at present a "science." The "hall mark" of a science is the ability to predict; the wide divergence of opinion among leading economists certainly does not lend confidence to their predictions. However, that is beside the present question.

Consider first the field of production. Until well along into the 19th century the world had made its living solely by handicraft—indeed a large amount of handicraft still survives. In 1776, some years before Hargreaves invented his epoch making spinning jenny and about the time Watt built his first imperfect steam engine, Adam Smith's great masterpiece, "The Wealth of Nations," which is conceded generally to be the foundation of modern economics, was published. Quite naturally that great philosopher viewed industry as handicraft; and while a large part of his conclusions on some topics still may apply, the economics of production have been changed greatly since his day.

During the years 1800–1850 the engineer was busy building up the modern tools of industry. As an economist he was of negligible importance. With the development of the semi-automatic and full automatic machine in this country about the middle of the century, modern manufacturing methods came into being; but not until a quarter of a century later did the new economic relations introduced by these methods attract the attention of engineers. About that time, however, engineers began to assume prominence as industrial managers and quite naturally they turned their scientific training to the consideration of the economic problems occasioned by the new methods.

In 1886 Henry R. Towne presented a paper before the American Society of Mechanical Engineers entitled "The Engineer as an Economist." In that remarkable paper Mr. Towne foreshadowed the coming development in industrial economics and suggested that as a means of furthering this movement a new division of the Society be formed to be known as the economic section. It was 30 years or more, however, before this idea took strong root in the Society, though occasionally some evidence of progress appeared such as F. A. Halsey's monumental paper in 1891 on premium wage systems. Near the end of the 19th century this growth culminated in the remarkable work of F. W. Taylor and his associates Gantt, Gilbreth, Barth, and others; their work ushered in a new era not only in factory work, but also in management in general, whether in farm, factory, shop, or government. Whereas 40 years ago industrial production was almost entirely empirical, today the economic principles of production and their limitations are determined quite fully, though it must be admitted that this knowledge is not as widely disseminated or used as it should be.

Full text of a paper presented at a joint meeting of the Econometric Society, The American Society of Mechanical Engineers, the American Society for Testing Materials, and the A.I.E.E., Chicago, Ill., June 30, 1933. *Not published in pamphlet form.*

However, the outstanding fact remains that the engineer of today has quite complete mastery over the economics of production and can predict with some certainty, not only the scientific characteristics of his product, but also its economic performance; and it should be noted especially that in the course of this development the engineer has acquired a knowledge and a control of the human element in industry that would have appeared to be impossible 50 years ago. For the most part this extended knowledge of modern industry is the exclusive property of the engineering profession.

As a result of this industrial development both in factory and farm implements, of scientific agriculture, and of modern methods of food preservation, we are now able to produce the necessities of life in an abundance never before dreamed of. If poverty or want of any kind exists it is not for lack of either material resources or facilities for developing them for our use. It is conceded generally that about 1900 we passed from a "deficit economy" to a "surplus economy" or from a "sellers market" to a "buyers market," and for the first time in the history of man there was a hope that poverty could be abolished. For a time it appeared that we had solved this age-old problem only to be cast into one of the worst depressions in our history; and as we emerge from the dust and debris of this debacle it is little wonder that the land is filled with discordant voices seeking the cause and cure of this reverse of fortune.

If the industrial, commercial, and financial world had remained as simple as it was, say, in 1885 our hopes of solving the problem of existence might have been fulfilled; but in developing these new industrial methods the engineer has developed also a most remarkable system of transportation both on sea and land, and to this he has added the telegraph and the telephone which with the modern newspaper literally has abolished distance and brought the world to every man's breakfast table. The net result is a social and economic system as sensitive as it is complex. Worse still, this system apparently has increased greatly the opportunities for graft, exploitation, and unfair business and legal methods, which appear at times to defy all law and authority. This statement may be questioned in the light of days gone by, but at any rate the new methods have interposed between producer and consumer a system of distribution more complex than any heretofore known and one that calls for immediate remedies. The remedial efforts needed are ethical, legal, and economic in their scope. We are not concerned here with the first, and are interested in the second only in so far as it affects economic considerations.

THE ENGINEER IN INDUSTRIAL MANAGEMENT

Adjoining the field of actual production and closely integrated with it is the field of industrial management. This may be visualized as embracing the managerial functions in productive industries, transportation, and sales. The engineer has been prominent as a manager of productive enterprises ever since the industrial revolution, but in recent years his activities in that direction have been greatly increased and widened as a result primarily of the increase in the scientific background of all industrial and related fields. His superiority as an administrator, other things being equal, lies in his scientific training and his intimate knowledge of industrial operations. When to these is added a knowledge of accounting and finance, the combination is the very best that can be had for work in industrial administration of any kind. The engineer's usefulness in this territory has been attested widely by the writings of individual engineers, by the work of committees of national engineering societies, and most particularly by the work of the American Engineering Council which was organized specifically to give voice to the ideas of engineers on economic topics on which they are, by experience and training, specially fitted to express an opinion. This usefulness also has been recognized in the appointment of engineers to the Reconstruction Finance Corporation and more recently by the appointment of Arthur Morgan as head of the Tennessee Valley development.

Now it is in this part of our industrial life that our greatest difficulties lie and the greatest reforms needed. Certainly it cannot be claimed that industry as a whole has been well managed or well financed, judging by the large number of enterprises seriously handicapped by interest on bank loans. Our transportation system which grew up under *laissez faire* conditions is chaotic and fails to function as a national service. Furthermore, the entire system of distributing industrial and agricultural products and marketing them is unorganized and costly to an extreme.

It is in the field of industrial management also that, apparently, we are embarking upon some important experiments if the measures now before Congress looking toward a larger degree of self-government in industry become law. It is not to be expected that the engineer can formulate solutions to these far reaching problems, but without doubt if he rises to his highest usefulness and prepares himself through study of these problems he can make a helpful contribution to the economics of this phase of our industrial life. Not all of these problems will lend themselves to the concise and accurate methods that he has employed in production, but in many cases the analytical methods of engineering will prove very helpful.

THE ENGINEER AND POLITICAL ECONOMY

Beyond the confines of this field again lies the broader problems which we include in the term "political economy," a field of thought much more vague and much more difficult of comprehension, where the status of the engineer is much more uncertain. It has been asserted quite frequently that the experience of the engineer in industrial economics should give him an advantage in this broader field. It is quite true that the engineering administrator is brought into close contact with such matters as taxes, tariffs, foreign trade, transportation problems, and financial problems; and it is quite frequently assumed that to these problems he can bring the same methods of solution that have proved to be so successful in production problems. In some instances this is true as illustrated by the excellent work already accomplished by the American Engineering Council in fields that a few years ago were unknown to engineers. Without doubt wherever basic facts can be obtained engineering methods (which after all are adaptations of the scientific method) are very effective in forming accurate conclusions. And if such facts are to be drawn from industrial data the engineer has a peculiar advantage in finding those facts.

Now in the usual case of engineering economics the variables involved are related and known quantitatively, at least in some degree, making a direct solution possible; but in the field of general economics exact facts are often difficult to obtain, and when obtained their relations are far from obvious. The evidence in general economics may be voluminous, the variables many and conflicting, and what is worse, they may be changing in character. In many such cases the well trained business man, or the lawyer, is just as capable, or more so, of drawing an accurate conclusion as any one else. Certainly the engineer has no advantage here unless the data are drawn largely from industrial sources with which he is more familiar than are others.

ENGINEERING AND ECONOMICS WIDELY DIFFERENT

As Prof. Seymour Garrett, himself a well trained engineer and also a successful teacher of economics, has well said:

> "I said above that the impossiblity of drawing valid conclusions directly from the observation of events applied as well to current as to past economic affairs. I am aware that there is at the present time, and has been for some time past, a disposition to assume generalized theory unimportant. It is assumed that detailed statistical inquiry will reveal truth aided only by common sense and general information. With this view, engineers, because of the nature of their own work and of their triumphs, have a natural sympathy. They instinctively applaud what they denote as an appeal to facts instead of theory. What they forget, and sometimes do not even sense, is that the problems of engineering and of economics present large differences of kind. This is partly because the phenomena with which engineering deals occur in simpler form than those of economics. It is commonly possible to see without conscious effort just what is the nature of the data needed for a proper solution. Also the basic generalized theory within which the engineer works has been developed so long since that he uses it automatically and almost unconsciously."

If, then, the engineer is to be an important figure in public affairs, he must acquire a broader technique than that which he ordinarily possesses and he must inform himself concerning a wide range of subjects of which ordinarily he knows little. Furthermore, he must acquire a wide knowledge of economic history and be able to trace the effect of economic changes over long periods of time. The broad economic problems that now trouble us are not isolated and circumscribed in character; most of them have long histories and many ramifications. It is true that some of the old economic theories developed in a handicraft age do not apply to our modern machine era, and the industrial engineer can do much to show their fallacious character; but on the whole, the engineer who aspires to solve modern economic problems must expect to do an unusual amount of studying before he can replace these old theories with others that are suited to our day and methods.

Perhaps no field of knowledge presents such a bewildering array of theories which purport to tie together groups of phenomena more or less vaguely connected. He is indeed a bold man who will speak dogmatically about problems in political economy who has not studied this so-called "dismal science" long and carefully as a preparation. If the engineer can apply his analytical methods to these vague relations and develop the basic facts through his more intimate knowledge of industry, he can become indeed a most useful factor in public life.

THE ENGINEER SHOULD AVOID ECONOMIC PROPHECY

In applying his methods to complex economic problems, however, the engineer should avoid dogmatic statements. In his own chosen field he may be quite dogmatic at times because here he has the power to prophesy and make good on his prophecies; but in the field of general economics he must be more careful. This is particularly true of mathematical deductions as to future trends such as some of the engineering fraternity are putting forth at this time.

Economic variables have an unfortunate habit of changing with new discoveries and changed conditions; it is very unwise, therefore, to extrapolate any curve involving economic variables. Thomas Robert Malthus writing in 1798 his remarkable "Essay on the Principle of Population," developed the principle that population increases in a greater ratio than food supplies. Had he been satisfied to leave his law in that form it would have sufficed. But to accent his statements he assumed that population *if unchecked* will double every 25 years and hence increase in geometrical ratio thus, 1, 2, 4, 8, 16, 32, 64, 128, 256, while subsistence in the same time will increase as 1, 2, 3, 4, 5, 6, 7, 8, 9. The dark picture thus presented has had a profound effect upon human thought; his mathematical statement is so startling that Malthus has come down to us, in the popular mind at least, as a Jeremiah fortelling our eventual death by starvation rather than as the writer of a treatise on population which is as good and convincing reading now as it was in 1798. While undoubtedly the general conclusions of Malthus are correct the *time* element in his theory has been modified greatly by modern transportation which has made available agricultural areas of which he had little knowledge. With new methods of canning and preserving food supplies, who can say that the production of synthetic food may not defer his evil day indefinitely?

In a rapidly moving age such as ours most economic prophecies should be taken with a grain of salt and most economic prophets regarded with some suspicion. If the engineer is to venture into these troubled waters with the idea of applying his well tried scientific methods, he should take thought also of the measure and limitations of these methods; otherwise he may bring discredit not only upon himself, but also upon the group that he represents.

Editor's Note: For a discussion of this article see p. 582–3, this issue.

Short-Wave Radio to South America

The results of a year's survey of transmission conditions between New York and Buenos Aires in the short-wave radio spectrum show that frequencies between 19 and 23 megacycles were best for daytime transmission, and those between 8 and 10 megacycles for nighttime transmission. A transition frequency was required in the early morning, but the useful periods of the day and night frequencies overlapped in the evening. No variations that could definitely be traced to a seasonal effect was found.

By
C. R. BURROWS
MEMBER A.I.E.E.

E. J. HOWARD
NON-MEMBER

Both of Bell Tel. Laboratories, New York, N. Y.

BEFORE the establishing of telephone service between the Bell System in this country and the network of the International Telephone and Telegraph Company in Argentina, Chile, and Uruguay, an investigation of short-wave transmission over this path was considered desirable. Although a considerable amount of data on short-wave transmission had been accumulated over a period of several years, mostly over the North Atlantic path between New York and London (see "The Propagation of Short Radio Waves Over the North Atlantic," by C. R. Burrows, *Proc. I. R. E.*, v. 19, 1931, p. 1634–59), there were several ways in which this path differed from any that had at that time been investigated with quantitative receiving apparatus.

Some of the differences in the 2 paths are as follows:

1. The contemplated north-south circuit is $1^1/_2$ times as long as the east-west.
2. The difference in time between terminals of the north-south path is one hour as against 5 hr on the east-west path; the path of transmission is nearly parallel to the "shadow line" instead of at right angles to it.
3. The seasons in Argentina are opposite to ours, while those in England are the same as ours.
4. Approximately $^2/_3$ of the path to South America is over land while that to England is almost entirely over water.

In order to determine the nature of the differences in transmission 24-hr tests were conducted once a week from October 21, 1928, to May 17, 1929. From then until the conclusion of the test, November 1, 1929, the test consisted of transmission every other week during the most important 16 hr of the day. The general type and procedure of these tests were the same as those employed in the investigation of transmission conditions to England. They included field strength, noise, and intelligibility measurements on 6.755, 10.55, 16.27, 21.42, 27.51 megacycles (44.4, 28.44, 18.44, 14, 10.9 meters).

The transmitter used was the same one employed in the transatlantic tests. (See p. 1635 of previously mentioned article in *Proc. I. R. E.*, 1931.) A power of approximately 5 kw was radiated from vertical half-wave antennas for all frequencies except the 2 highest for which a power of only 1 kw was radiated. Field strength measurements were made on a set previously described (see "A Radio Field Strength Measuring System for Ferquencies up to 40 Megacycles," by H. T. Friis and E. Bruce, *Proc. I. R. E.*, v. 14, 1926, p. 507–21). Antennas used with these sets consisted in each case of single vertical wire elements which were calibrated at each frequency against a standard loop as suggested in the last-mentioned article.

FIELD STRENGTH SURFACES

Average transmission conditions over this path are shown at a glance in Fig. 1. It gives the field strength as a function of the time of day and the frequency. Points within the 2 black regions specify conditions when the signal is not received. The level of this region is probably much lower than −20 decibels indicated at the boundary; the sensitivity of the measuring set and noise precluded the determination of the exact level. The first black region represents the poor nighttime transmission on the higher frequencies; the second depicts the period in the daytime when the lower frequencies fail. The individual diurnal variation curves show a tendency for a daytime valley to be present even on 27 megacycles. Another fact that is averaged out in the surface is the tendency of the field on the lower frequencies to be slightly higher just after it comes in and before it goes out than it is during the rest of the useful period.

The change of seasons does not produce a marked effect in the transmission conditions over this path; the data do not indicate any difference between the quarters for the equinoxes or between the quarters for the two solstices. This behavior is due to the opposition of the seasons over the north and south halves of the path. Some seasonal effect probably remains in spite of this tendency toward cancellation, but it is of minor importance and difficult to separate from the large day-to-day variations resulting from other causes. It seems likely to the writers that for this path the solar cycle has a more marked effect than the cycle of the seasons. (Conclusions should not be drawn from data from one year only in view of possible differences in solar activity, e. g., a 15-month solar cycle. See "The

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Full text of a paper published in the *Proc. I. R. E.*, v. 21, 1933, p. 102–13. *Not published in pamphlet form.*

Influence of Sunspots on Radio Reception," by H. T. Stetson, *Jour. Frank. Inst.*, v. 210, 1930, p. 403–19.) This is in marked contrast to conditions over paths well away from the equator, for example, those over the North Atlantic.

The surfaces of all diagrams including those drawn for different seasons, show that generally speaking frequencies between 19 and 23 megacycles were best during the daytime, and those between 8 and 10 megacycles were to be preferred at night. Sometimes lower frequencies gave higher field strengths but this advantage was usually offset by a higher noise level.

When the daytime absorption on the lower frequencies is still pronounced on 21 megacycles, a higher frequency may give stronger fields. This was the case with the 27-megacycle frequency on several of the test days.

Another weak period occurs at the time when it is necessary to change from a night frequency to a day frequency (6 or 7 o'clock, E. S. T.). This was the most difficult time for transmission during the year of these tests. There was usually a lapse of about 2 hr between the time of high fields on the night frequency and the time of high fields on the day frequency. The most help at these times would come from an intermediate frequency such as 16 megacycles.

Day-to-day variations were very much less on the lower frequencies than on the higher ones. On the 2 lower frequencies, 6.7 and 10.5 megacycles, the times when the signal came in were very nearly the same on all of the test days. The same can be said of the time when it disappeared. Between these times the field strength curve was comparatively flat and high. On the 2 higher frequencies, 27 and 21 megacycles, on the other hand, the field strength curves showed considerable variation among themselves. Sometimes the curve on these frequencies had one high level region, sometimes it exhibited 2 or more peaks, and at other times the first peak would be absent resulting in weak signals during the early part of the period.

It is indicated in Fig. 1 that between 14 and 18 megacycles a frequency can be chosen which is influenced both by the nighttime skip depression and by the midday absorption minimum. The combining of these opposing tendencies in one diurnal characteristic will result, so to speak, in the cancellation of the component having a 24-hr period, and will leave instead a second harmonic of the daily cycle. The test frequency 16.27 megacycles often exhibited this characteristic. Day-to-day variations in the transmitting medium changed the type of the characteristic on this frequency in an erratic manner. Sometimes it resembled a night frequency, though more often it had day frequency characteristics. It seems likely that a study of these fluctuations may assist in the determination of the causes of the day-to-day fluctuations in the medium.

A few tests were conducted on 31 and 36 megacycles. The 31-megacycle frequency was received on all of the test days at some time during the period 10:00–15:00 E. S. T. field strengths as high as the maxima measured on 27 megacycles were sometimes obtained. The diurnal variation curves are so different for the different days that an average curve would be misleading. This frequency of 31 megacycles has little commercial value because of the irregularity of the time it is received.

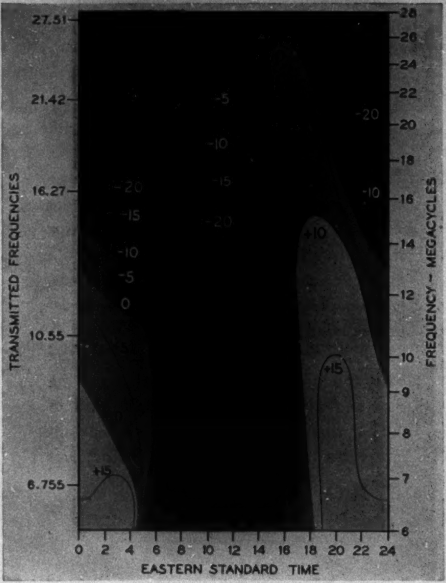

Fig. 1. Average field strength surface for October 12, 1928 to November 1, 1929. Decibels above one microvolt per meter for one kilowatt radiated

Thirty-six megacycles was never received. The maximum signal at 36 megacycles during any of the tests must have been at least 15 decibels below that on 31 megacycles since a signal of this intensity could have been detected with the receiver employed. This would seem to indicate that the upper limiting frequency for this path lies near the range of 31 to 36 megacycles.

It may be well to point out that measurements of the type here presented are not independent of the type of transmitting and receiving antennas employed. This is due to the fact that the transmitting medium shows a preference for signals having a certain angle of departure and a certain angle of arrival. In order to determine the loss occasioned by the medium, the efficiency of the antenna in these directions must be taken into account. At best a complicated process, this becomes very difficult if not impossible when transmission occurs over several paths simultaneously as, in all probability, it usually does.

It is conceivable that these considerations may explain to some extent the erratic behavior of the highest frequencies used in these tests. For 31 megacycles the preferred angles may be so near to the horizontal that the low efficiency of the antennas in this direction made reception very difficult. It has been found (see "Some Effects of Topography and Ground on Short-Wave Reception," by R. K. Potter and H. T. Friis, *Proc. I. R. E.*, v. 20, 1932, p. 699–721) that 21-megacycle signals from South America are strongest for antennas with low angle polar characteristics in the vertical plane.

DISTURBED DAYS

Transmission over this path has not been as adversely affected during periods of solar activity as that over the North Atlantic. The relative effects of solar activity on the 2 circuits are illustrated in Fig. 2. These curves show the received field strength on the day frequency for the 2 paths. The curves for August 7, 1930, show the conditions during a period of solar activity. The curves for August 5, 1930, show conditions on an undisturbed day preceding this period of solar activity. These curves show that transmission conditions were much more adversely affected on the transatlantic path than on the South American one. Although this was one of the more severe solar disturbances, telephone communication to South America was not seriously affected.

TRANSMISSION CONDITIONS OF INDIVIDUAL DAYS

Comparison of the average conditions set forth in Fig. 1 and similar diagrams with typical daily curves which were obtained, showed that marked differences occur from day to day. Without attempting to illustrate each point, the following characteristics may be mentioned in order to portray different types of the variations which occur:

1. The daytime absorption minimum which is always present for the lower frequencies frequently seems to extend as high as 21 megacycles and perhaps even higher. At these higher frequencies the depth of this minimum is not ordinarily sufficient to interfere with commercial traffic.

2. At 27 megacycles, great variability exists in the duration of the period when strong signals are received.

3. Occasionally 16 megacycles can be received through the full 24 hr. Usually it takes on the characteristics of a day or night frequency, and sometimes it shares the weak periods of both day and night waves.

4. The low frequencies (6.755 and 10.55, inclusive) behave the most consistently as regards the times of the beginning and ending of the useful period.

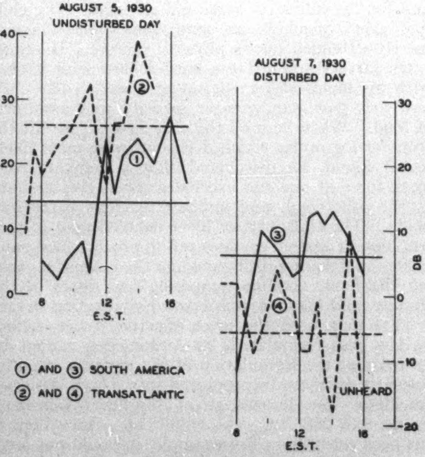

Fig. 2. Diurnal variation curves on the day frequency showing relative effects of solar activity on transatlantic and South American transmission

The reduction in field strengths on the disturbed day, August 7, 1930, is less pronounced on the South American path (compare curves 1 and 3) than on the transatlantic path (compare curves 2 and 4)

COMPARISON WITH TRANSATLANTIC TRANSMISSION

With the aid of the data presented in the last mentioned article (*Proc. I. R. E.*, 1932, p 699–721) the following comparisons may be made between transmission over the North Atlantic and to South America:

1. With similar facilities, it should be possible to maintain a better grade of service throughout the 24 hr between New York and Buenos Aires than between New York and London.

2. On the New York-Buenos Aires circuit, the interruptions due to disturbed solar conditions were fewer and of shorter duration than on the circuit to London.

3. There was no weak period at sunset in the New York-Buenos Aires transmission as there is in the New York-London transmission.

4. For frequencies around 27 megacycles there is better transmission to Buenos Aires than to London. This is due in part to the greater length of transmission path, but may also be due to other factors, such as more intense illumination from the sun and greater separation from the magnetic poles. (The reason for the effect of length of path is obtained from consideration of the fact that, for the same conditions of the Kennelly-Heaviside layer, the higher frequencies are not returned to the earth within as short a distance as the lower frequencies. That is, the skip distance is longer for the higher frequencies. Greater ionization due to more intense illumination from the sun tends to decrease the skip distance.)

5. At midday there is greater absorption on the lower and intermediate frequencies on the South American than on the transatlantic path. This absorption dip was even noticeable on all the transmitted frequencies 6.7, 10, 16, 21, and 27 megacycles on more than half of the test days. The greater length of path and more intense illumination from the sun are in the right direction to cause this greater absorption.

6. Transmission conditions to Buenos Aires on a given frequency are in many ways comparable with those to London on a frequency 33 per cent lower. This was particularly noticeable at the transition frequencies (about 16 megacycles to Buenos Aires and about 10 megacycles to London).

7. For the South American circuit the changes between night and day transmission conditions are more abrupt than on the transatlantic path. This is presumably due to the fact that the times of sunrise and sunset are more nearly the same at the transmitter and receiver on the former than on the latter.

8. The seasonal change in transmission conditions is very much less pronounced between New York and Buenos Aires than between New York and London. In fact no variations that could unmistakably be attributed to seasonal changes have been found for the former path.

9. The results of these tests do not substantiate the view that transmission over this path is more difficult during an equinox than during a solstice.

10. The atmospheric noise has the following general characteristics at both locations: (*a*) the noise increases with decrease in frequency; (*b*) the range of its diurnal variation increases with decrease in frequency; and (*c*) the maxima of the noise and signal diurnal variation occur at approximately the same time, and likewise their minima.

The Machine—An Aid to Humanity

A history of the earliest discovery and development of machines is presented herewith as a simple and fundamental proof that machines are agents working for the benefit of humanity, and not, as so many are now maintaining, for man's harm.

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IN reading about and in listening to the many explanations of the causes of and remedies for the present economic and industrial depression one is impressed by the persistence of a fundamental idea contained in many an ancient belief or superstition. One of these ancient tenets that still seems to be functioning is the belief in demons or spirits. The ancients believed that 2 demons or spirits, one good and one bad, controlled the destiny of every human being. The good demon was credited with the meritorious deeds of his ward, while opprobrium was accorded the bad demon for his ward's evil deeds. Gradually man began to claim personal credit for his meritorious performance, but to this day the evil demon is still on duty. Man still ascribes many of his own delinquencies and shortcomings to forces outside his own control, that is, to evil demons. These evil demons go by different names, the most common today being capitalism and its associate, the machine.

A few of the charges hurled at the machine are that it destroys reverence for human life; that it merely extends the physical powers of man but exerts no spiritual force; that man is fast becoming a mere valet to a machine; that it is a dysgenic or atrophying factor comparable to the use of narcotics; that it is one of the great faults of civilization; or in short, that it is responsible for most, if not all, of man's social, industrial, spiritual, and aesthetic shortcomings. Most certainly this is a grievous load for the demon machine to bear.

THE ORIGIN OF FIRE

But what is a machine, and how has it come into being? The origin or beginning of the machine, like the beginnings of most of man's achievements, is lost in antiquity. The sinanthropus or Peking man left no remnants of tools or of machines. Nevertheless, sometime in his ascent to civilization man first used fire—which is the demon in the modern machine—to cook his food and to temper the rigors of the climate. The ability to kindle a fire was undoubtedly one of the most momentous forces in the development of civilization, but the kindling of a fire by the mere rubbing of one stick was an arduous task, as any boy scout can testify. How many generations, ages or aeons, of time passed before man transformed his fire stick into a fire drill is again one of the dark pages of history.

One of the steps in the evolution of the fire drill was the discovery that the drill could be rotated or twirled by wrapping a leather thong around it and then pulling the thong back and forth. This released one hand of the operator, but 2 persons were still needed to kindle a fire. By fastening the ends of the string or thong to the ends of a bow, a machine was created, and one man could do the work of 2. The first machine, therefore, created unemployment. You smile at such a naive and silly suggestion. In order to show the fallacy of some seemingly valid logic it is necessary to show the absurdity of snap conclusion. In short, it may be said in all seriousness, that every day more important conclusions are being drawn from weaker premises.

THE LEVER COMES INTO USE

Sometime in the evolution of his mental powers, our ancient forebear became acquainted with another simple machine or tool, the club. Undoubtedly in his most primitive state he did not know that a club was a useful tool for defense against his enemies and for the killing of game for his food. The club, like every machine as some philosophers assert, merely extended man's physical powers. He could reach farther and strike a harder blow with it than with his hand, either opened or closed. The club, however, gave him greater security and assurance of food. When he used the club as a pry to lift the stone or log under which delicacies were most likely to be found, he discovered that a comparatively weak force at one end exerted a much greater force at the other end, and another machine came into being. The club, pry, or lever enabled man to protect himself against enemies and to procure food more easily, and the fire drill gave him the means for cooking the food, and for tempering the rigors of the climate, and man's march toward civilization began.

That men used the lever effectively ages before its law was formulated by Archimedes cannot be denied, but the formulation of the law was essential before it could be incorporated into a well designed machine. The knowledge of the lever possessed by man to 212 B.C. was empirical. Since then it has been scientific. For example, it would not have been possible to use the lever in the measurement of weights without a knowledge of the relations between the acting and reacting forces and their relative distances from the fulcrum. When this principle was experimentally determined and formulated into a law, at once the scientific basis for the application of the lever was established.

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The lever, when used as a pry, enabled one man to exert a force of many men, thus also creating unemployment; and when used as a balance it undoubtedly displaced many official guessers. Nevertheless, it not only made possible commerce on some basis of equity, but it has entered, in one form or other, into nearly every machine that has been made. Probably no machine is more complicated than the modern high speed printing press or an automatic automobile chassis-riveting machine. But no matter what the form or purpose of the machine, the principles of the lever are involved in its operation.

HISTORY OF MACHINES SHOWS THEIR BENEFICIAL INFLUENCE

All of this elaboration of details may seem to some as irrelevant, but when a prominent divine insists that a machine destroys reverence for human life, and when a former secretary of war says that the bane of civilization is too many inventors, it becomes necessary to give some consideration to the process by which machines came into existence and to their influence on man's well being.

It is doubtful whether any reader would assert that either the discovery of the lever or the invention of the fire drill was in any manner detrimental to the well being of man. Nevertheless, the discovery of methods of kindling and maintaining a fire, combined with the principles of the lever, has made possible the modern industrial civilization with all its advantages and disadvantages.

Mythology ascribes man's attributes of knowledge and wisdom to the agency of fire which the Titan Prometheus stole from the gods. This classical myth is artistically depicted by the poet Longfellow in the following words:

> "Beautiful is the tradition
> of that flight from heavenly portals,
> The old classic superstition
> of the theft and the transmission
> of the fire of the immortals!"

But what has that to do with machines? Well, if Prometheus, that is, the coordinated forethought of many generations of men had not shown how fire can be made to do work, none but the simplest machines would ever have been made.

It is work to draw the bow back and forth against the friction of the drill and the block. It is work to lift on one end of a pry or lever when lifting a stone or rolling a log. We call the ability or capacity to do work energy. The machine requires energy from some source for its operation, and some material upon which to operate. Push and pull, push and pull, is all that it requires, and the final result of the push and pull is increase in temperature, and finally fire. In short, the operator of the fire drill expended energy which was converted into heat at the point of the stick, but it took ages to reverse the process and convert the heat into a push and a pull.

Early man did not know that the heat which ignited his tinder was merely the energy of his muscles appearing in another form. While every high school student of physics of today should know it, nevertheless the many attempts to build a perpetual motion machine of one form or another is evidence of the incomplete understanding even today of the laws of conversion and conservation of energy. The primitive man knew that the wind, falling water, animals, and man himself could exert a push and a pull. Did I say primitive? Well, we should hardly call our forefathers down to the beginning of the nineteenth century primitive. In some respects they were more civilized than we are, and yet they did not know that the heat produced by the constant sawing back and forth of the operation was merely another form of the energy expended, until 1798 when Count Rumford showed that the heat produced was an equivalent of the work done. When the fact that heat is energy was fully realized, another important step in the development of the machine was taken.

This step was so important and fundamental in the development of the modern machine that further elaboration of the idea is justified. Let me repeat: the causal differences between our civilization and that of the ancient Greeks, for example, is the law of the conversion and conservation of energy and the related laws of dynamics. The Greeks knew the laws of the simple machine, the lever, and of the inclined plane, but they did not know the method or process by which the heat of combustion of fuel could be utilized to produce a push and a pull. In fact, the principle of converting heat into mechanical work was not known until the invention of the steam engine in 1768, a few years before the discovery of Count Rumford that mechanical energy and heat were merely different forms of the same entity. This application of a principle before the formulation of its law is nothing new in human history. The lever was used a long time before its laws were known, and just as it was impossible to design even a steel yard before the law of the lever was formulated, so it was impossible to design an efficient steam engine before the formulation of the laws relative to the equivalence of heat and mechanical energy.

Every reader knows that a reciprocating steam engine is merely a device for converting heat into a push and a pull. By means of a combination of levers, cams, and some other mechanical devices, this push and pull is made continuous. The push and pull of the operator of the bow drill is now reproduced by the back and forward motion of the piston, and the rotary motion of the fire stick is reproduced in the rotary motion of the crank and shaft of the engine.

MACHINES MULTIPLY MAN'S POWERS

The motions of the 2 machines, fire drill and reciprocating engine, are almost identical, but there is one fundamental difference involved in their operations. The strength, force, or energy of man and man alone produced the motion of the fire drill. The heat generated was a result of man's work. Heat of burning fuel produces the motion of the piston of the steam engine. The use of energy other than that of his muscles has increased man's physical powers beyond calculation. No wonder that some misunderstanding minds consider the machine a Frankenstein monster about to destroy his maker. But man is not the servant or slave of the machine, but its lord and master. The machine is the product of man's mind combined with the ingenuity and skill of his hand. It does his bidding, serves him with comforts, and enables him to change his physical environment, and is an essential condition of progress. This idea is expounded by Dr. A. N. Whitehead in his book on "Science and the Modern World" when he says: "Those organisms are successful which modify their environment so as to assist each other. For example, the North American Indians accepted their environment, with the result that a scanty population barely succeeded in maintaining themselves over the whole continent. The European races when they arrived in the same continent pursued an opposite policy. They at once cooperated in modifying their environment. The result is that a population more than 20 times that of the Indian population now occupies the same territory." This maintenance of a larger population in the same territory is not even $^1/_2$ of the story. It is not merely sustenance that European races have achieved, but they have also achieved a life never dreamed of in the Indian's philosophy.

Machines have enabled man to move "from the forests to the plains, from the plains to the seacoast, from the continent to the sea, from climate to climate, and from habit of life to habit of life."

SCIENCE SWAYS MEN'S MINDS

It was previously stated that the causal differences between our modes of life and those of the ancient Greeks are the laws of the conservation of energy and the associated laws of dynamics. These laws condition the operation of machines, and not only the operation of machines, but also the operation of men's minds. The development of the former has been touched upon, but the latter is just as significant. Ideas are often powerful and dominant when the foundation is mere assumption and authority but when they are founded on fact their power is irresistible. Then they mold both the physical environment and the thoughts of men, and they both make new civilizations and destroy the old. Again, how is all this related to the electrical machine which seems to be the bone of contention today?

The science of electrodynamics does not begin with the study of electrified amber by Thales at Miletus in the seventh century B.C., nor with the researches of William Gilbert, physician to Queen Elizabeth. While the former first recorded some of the properties of electrified bodies, and a knowledge of these properties is essential to the understanding of electrical phenomena, and while the studies and experiments of Gilbert on magnets are fundamental in the future study of magnetic phenomena, their studies had no relation to force and motion or dynamics.

The early investigators and experimenters with electrified glass and amber rods, and with loadstone and magnetized pieces of iron were not attempting to furnish a political issue to the legislators of the 20th century. They were merely studying certain natural phenomena and attempting to determine by experiment the influence of different conditions of those natural properties of magnetism and electrification. The shepherd on the plains of Asia Minor, when he discovered a peculiar stone that attracted the iron hook of his shepherd's staff, had no vision of that force pulling a train of cars over the mountains in Montana, Idaho, and Washington. That is, he knew no way of utilizing the force of magnetism in the production of a push and a pull. Neither did the experimenters, with the electrified glass and amber rods, have any conception or notion that some day that property which they had named electricity, would enable man to convert the force discovered by the shepherd into a push and a pull. At first the property of the lodestone, called magnetism, and the property of the amber rod, called electricity, were totally dissociated phenomena, apparently as unrelated as air and water. Nevertheless, after centuries of painstaking investigation, analyses and coordination, it was discovered that if the electricity were made to move, an influence or force would radiate out into space from the wire conveying the electricity, and that if a magnet were anywhere near the current carrying wire it would be deflected. No one even today knows exactly how the force is transferred, and yet the fact that it is transferred is the scientific basis for the public utility controversy now rampant. This, together with another related discovery, stands parallel to the discovery of the means of converting heat into a push and a pull as the most influential in the molding of civilization. Not all the philosophies composed since the time of Aristotle have exerted such a profound influence upon the lives of men. Magnets and electricity at rest are important and significant, but it is their interaction in conformity with the laws of dynamics, that turns the wheels of commerce and makes the highways like unto day.

CONVERSION OF MOTION INTO ELECTRICITY DISCOVERED

The discovery of the fact that a current carrying wire exerted a force on a magnet when coupled with another of equal moment, a new device for converting energy into a push and a pull, resulted. This discovery is just the converse of the one previously referred to. For, reasoned Faraday, if a current carrying wire is surrounded by a magnetic field or influence which moves a magnet, will the surrounding of a wire by a magnetic field produce a current in the wire? With what suppressed emotion he must have watched the magnetic needle of his testing instrument to see if it moved when he thrust one end of a bar magnet into a coil of wire, the ends of which were connected to the testing instrument. It would not have been surprising if he had yelled "Mirabile dictu, it moves! it moves!" For it did move and the motion showed that the relative motion between a magnetic field and a coil of wire produced an electric current which in turn produced a magnetic field, and the wedding of thought with fact showed that the phenomenon observed by the shepherd in Asia Minor and the phenomenon observed by Thales were different phases or aspects of the same thing. That was the purely scientific result, but the practical consequences were and are just as momentous. The steam engine is a machine which converts the energy of coal or other fuel into energy of motion, and Faraday's discovery permits the conversion of motion into another form of energy.

The electric generator is an intervening agent in the process of converting energy. Through the instrumentality of the boiler and steam engine, the energy of burning fuel is converted into energy of motion. This motion by some form of mechanical connection is transferred to coils of wire or to electromagnets which are made to move relative to each other. The energy of this relative motion is then converted into energy of an electric current, and thus Faraday's moving a magnet relative to a coil is the source not merely of a revenue of $2,155,000,000 and of wealth beyond the most avaricious dreams of Croesus, but of ways of life. The electrical machine has assumed fundamental importance in modern civilization, and yet, relatively few understand its position in the industrial and economic fields.

Only recently a former candidate for governor of New York asserted that previously industry depended upon steam for its source of power, but now it depends upon electricity. This is another superficial observation. It conveys the idea that an electric generator is an original or immediate source of energy. An electric generator is no more self operating than the fire drill, but whereas man's muscles provided the force to operate the fire drill, the force to operate the generator comes from burning coal or a waterfall. Industry still depends upon the energy of the steam for its operations, but because electricity can be conveyed long distances efficiently, the manufacturing or industrial plant need not be located near the steam engine or waterfall.

SUMMARY

In conclusion there is presented a summary of the essential features of the preceding arguments, and likewise a brief refutation of some of the more common and prevalent charges that machines are our evil demons responsible not only for our economic and social ills, but for our lack of idealism and spirituality.

We need no vivid imagination to picture to ourselves the plight of primitive man who was subject to all the vicissitudes of the changing temperatures of the seasons and to the rigors of changing climates. His sole means of securing sustenance was the skill of his hands and the fleetness of his feet. His shelter against the rigors of the storms and climate was a cave or a rude hut of sticks covered with bark, or with the skins of either domestic or wild animals. The food he had to eat raw until through the ages he acquired the skill to build and maintain a fire. Before he devised a machine for the building of the fire, if the fire died, he had to beg or steal from another, and thus in a measure he was subservient to the more fortunate. When, however, he devised the fire drill, he became more independent and self reliant. Thus the simplest machine was an agent of freedom and independence and not of enslavement.

The next great step in human progress was the discovery of the method of making fire or heat do the work of men and of animals. The steam engine made factories possible, and these factories to some are merely prison walls, but the prison walls are not the work of the machines. If factories are prison walls, the fault is of human origin and not that of the inanimate machine that does man's bidding. Granted that man must toil to secure the goods to satisfy his wants, the charge of enslavement is based upon the assumption that before the introduction of the factory man was free. This was the notion of Ruskin whose conception of "an ideal life was a peasant in a velvet jacket singing in the fields, the heavens unpoluted by the smoke of mills and the air unvexed by the noise of railroads." A beautiful picture indeed, but Ruskin does not tell us how the peasant was to get the velvet jacket. Before the invention of the power loom most peasants were glad to have coarse homespun to cover their nakedness and to keep out the inclement storm. The lot of the peasant before the invention of machines is more accurately portrayed by Millet in his "Man With the Hoe" and "The Angelus" and by the East Indian woman hitched to an ox plowing in the field, than by Ruskin's happy meadow lark.

When man learned to experiment and to study the operation of natural laws, he soon developed means for molding his environment, not merely for supplying his creature comforts, but for stimulating his aesthetic sense and intellectual aspirations. In short, natural science was born. The most potent mechanical product of science is the electrical machine which in the brief space of half a century has almost completely transformed civilization. Politicians and statesmen are much agitated over the more obvious services of the electrical machine, such as the supplying of light and power. While these are of great importance as they are subject to taxation and satisfy our needs, these are not so significant, and it may be said important, as many of the services never mentioned in the halls of congress or legislatures. If the electric generator had not been invented there would be no automobiles, no airplanes, no telephones, no telegraphs, no radio, no television, no X rays, and no electrocardiograph; nor would there be a host of other devices by which man not only secures a broader experience, wider outlook, but by which his ailments are diagnosed and cured.

The progeny of the electric generator is truly numerous and magnificent, but it is ever growing larger and more splendid. Not merely the physical sciences such as physics and chemistry are dependent upon electricity for further development, but the new and profound researches in the biological sciences are conditioned by electricity, the subtle product of the electric generator. Thus the electric machine is not only the product of science, but it is the agent that makes scientific discoveries possible. The machines, products of man's mind and skill, are also the agents by which his mind and body are set free.

Metering of Symmetrical Components

Methods of metering the positive and negative sequence power and energy in 3-phase 3-wire systems, and positive, negative, and zero sequence power and energy in 3-phase 4-wire systems, are discussed in this article. It is presented not because it contains a wealth of new material, but because it deals comprehensively with the problem, in a way different from that which has prevailed in earlier published material, and because it is clear, specific, and readily understandable, confining itself strictly to the problem of metering of symmetrical components.

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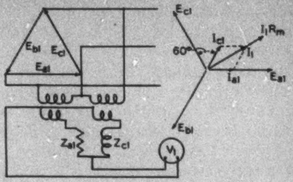

Fig. 1. Positive sequence voltage

CERTAIN NET WORKS designed to meter simultaneously and separately the positive and negative sequence components of power or energy are described in this article. Tables are included showing the location and number of instrument transformers required for each network, and equations involving the design of the impedances of the metering systems are given. It is suggested that the components of power be utilized in relays and control equipment, as well as the components of current and voltage.

Contents of previous publications on metering of symmetrical components have been confined largely to the components of current and voltage in 3-phase 3-wire systems. The method of resolving an unbalanced 3-phase system into the 3 symmetrical components—a balanced 3-phase positive-sequence system, a balanced 3-phase negative-sequence system, and a uniphase or zero-sequence system—has been described in a number of articles in current periodicals and books (see references 1–5). The utilization of these components in the solution of practical problems, such as the calculation of short circuit currents in transmission lines (see references 6 and 7), and the behavior of induction motors and synchronous machines under unbalanced conditions (see references 8–11) is described in other articles. Certain metering networks (see references 2, 12, and 13) have been proposed for measuring the voltage and current components of these symmetrical systems. Relays have been developed which function in response to the negative sequence current; voltage regulators utilize the positive sequence voltage of a system, rather than one of the line voltages. No doubt these symmetrical components, particularly the power components, will be put to many other uses in electrical control and metering equipment when the limitations, errors, and cost of the various networks required to separate them are more extensively known.

It has been shown in these other articles referred to, that when no zero sequence components are present, networks may be set up which will meter simultaneously and separately the positive and negative sequence voltages as shown in Fig. 3, and the positive and negative sequence currents as shown in Fig. 6. It is thought advisable, however, to go into considerable detail in the analysis of the voltage and current networks, to establish more clearly certain facts useful in the explanation of power and energy metering networks.

In order to simplify the vector diagrams and notation, the secondary voltages and currents of all the instrument transformers are assumed to have the same value and phase position as the corresponding primary values. Obviously, this notation will not affect the result since all the vectors will be reversed.

The following symbols will be used in this article:

E_a, E_c, E_b, E_0 phase voltages of an unbalanced system
I_{bc}, I_{ca}, I_{ab} line currents of a 3-phase 3-wire system
E_{a1}, E_{c1}, E_{b1} positive sequence voltages of the system
E_{a2}, E_{c2}, E_{b2} negative sequence voltages of the system
E_0 zero sequence voltage of the system
I_0 zero sequence current of the system
I_{bc1}, I_{ca1}, I_{ab1} positive sequence line currents of a 3-phase system
I_{bc2}, I_{ca2}, I_{ab2} negative sequence line currents of a 3-wire system
I_a, I_c, I_b, I_0 line currents of a 3-phase 4-wire system
Z_{a1}, Z_{c1} impedances of the positive sequence potential network
Z_{a2}, Z_{c2} impedances of the negative sequence potential network
R_m internal resistance in series with the moving element of a standard wattmeter or voltmeter
Z_m impedance equal to that of the current coil of the wattmeter or ammeter
R effective resistance of the potential coil of the watthour meter
W_1 positive sequence watts
W_2 negative sequence watts
W_0 zero sequence watts
r resistance of the load current network
s impedance of the load current network
X_L reactance of the potential coil of the watthour meter
X_C condensive reactance $= X_L$
${}_rI_{bc}$ component of I_{bc} flowing through r
${}_sI_{bc}$ component of I_{bc} flowing through s.
${}_rI_{ca}$ component of I_{ca} flowing through r
${}_sI_{ca}$ component of I_{ca} flowing through s
I_{a1} current flowing through current coil of any positive sequence meter

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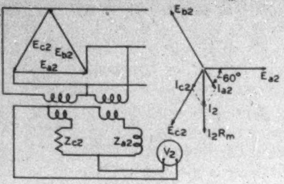


Fig. 2. Negative sequence voltage

I_{s2} current flowing through current coil of any negative sequence meter
I_{a1}, I_{c1}, I_{a2}, I_{c2}, etc., currents flowing through impedances having corresponding subscripts
I_1 current flowing through the potential coil of any positive sequence meter
I_2 current flowing through the potential coil of any negative sequence meter.

METERING OF POSITIVE AND NEGATIVE SEQUENCE VOLTAGES

In using a standard voltmeter combined with a potential network to measure the symmetrical components of voltage, the high internal resistance R_m is removed, leaving only the negligibly small resistance of the moving element of the meter. Consequently the network impedances which take the place of R_m, together with the line voltages, entirely control the magnitude and phase position of the potential current of the meter.

The complex components of the network impedances may be any value provided the following general equations are satisfied:

$$Z_{c1} = j^{2/3}Z_{a1} \tag{1}$$

$$Z_{a2} = j^{2/3}Z_{c2} \tag{2}$$

$$Z_{a1} = Z_{c2} = Kj^0R_m \tag{3}$$

If the voltmeter is to be direct reading, the numerical value of the constant K must be equal to $\sqrt{3}$.

In order to more clearly explain the function of the network impedances, assume that a positive sequence network can be applied to a positive sequence set of voltages as shown in Fig. 1.

Let $Z_{a1} = \sqrt{3}\, j^0\, R_m$. An inspection of the network and the vector diagram shows the validity of the following equations:

$$I_{a1} = \frac{E_{a1}}{Z_{a1}} \tag{4}$$

$$I_{c1} = \frac{E_{c1}}{Z_{c1}} \tag{5}$$

$$I_1 = I_{a1} + I_{c1} \tag{6}$$

The equivalent voltage indicated by the voltmeter is:

$$I_1R_m = j^{1/3}E_{a1} \tag{7}$$

Consequently the meter indicates the positive sequence voltage when the network is applied to an assumed positive sequence system.

Again, assume that a negative sequence network can be applied to a negative sequence set of voltages as shown in Fig. 2.

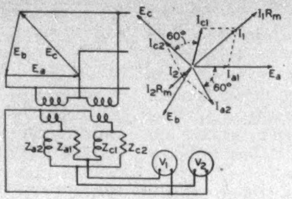


Fig. 3. Positive and negative sequence voltage

Let $Z_{c2} = \sqrt{3}\, j^0\, R_m$. An inspection of the network and vector diagram shows the validity of the following equations:

$$I_{a2} = \frac{E_{a2}}{Z_{a2}} \tag{8}$$

$$I_{c2} = \frac{E_{c2}}{Z_{c2}} \tag{9}$$

$$I_2 = I_{a2} + I_{c2} \tag{10}$$

The equivalent voltage indicated by the voltmeter is:

$$I_2R_m = j^{1/3}E_{c2} \tag{11}$$

Consequently the meter indicates the negative sequence voltage when the network is applied to an assumed negative sequence system.

Although it has been shown that the component voltmeters indicate correctly when the networks are applied to the respective component systems, it remains yet to be proved that the voltmeters will indicate correctly when the networks are applied to an unbalanced set of voltages. A proof of this is shown in the following equations:

$$I_1 = \frac{E_{a1}}{Z_{a1}} + \frac{E_{c1}}{Z_{c1}} \tag{12}$$

and

$$\frac{E_{a2}}{Z_{a1}} + \frac{E_{c2}}{Z_{c1}} = 0 \tag{13}$$

$$I_1 = \frac{E_{a1} + E_{a2}}{Z_{a1}} + \frac{E_{c1} + E_{c2}}{Z_{c1}} = \frac{E_a}{Z_{a1}} + \frac{E_c}{Z_{c1}} \tag{14}$$

also

$$I_2 = \frac{E_{a2}}{Z_{a2}} + \frac{E_{c2}}{Z_{c2}} \tag{15}$$

and

$$\frac{E_{a1}}{Z_{a2}} + \frac{E_{c1}}{Z_{c2}} = 0 \tag{16}$$

$$I_2 = \frac{E_{a2} + E_{a1}}{Z_{a2}} + \frac{E_{c2} + E_{c1}}{Z_{c2}} = \frac{E_a}{Z_{a2}} + \frac{E_c}{Z_{c2}} \tag{17}$$

It is apparent, in comparing eq 12 with 14, and 15 with 17, that the networks produce the same result, and hence the correct result, when applied to any unbalanced set of line voltages as when they were applied to their respective component voltages.

In Fig. 3 is shown the positive and negative sequence networks of Figs. 1 and 2 combined and applied to an unbalanced set of voltages. If the phase sequence of the line voltages happen to be reversed from that shown in Fig. 3 the network would function, but the voltmeter V_1 would become voltmeter V_2, and V_2 would become V_1. The larger reading voltmeter is the positive sequence meter except in very extreme cases of unbalance.

POSITIVE AND NEGATIVE SEQUENCE CURRENTS

In using a standard ammeter to measure the positive and negative sequence current of a 3-phase 3-wire system a current network is utilized, which consists of a low resistance r, a low impedance z, and an impedance Z_m, equivalent to the impedance of the

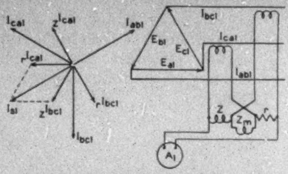


Fig. 4. **Positive sequence current**

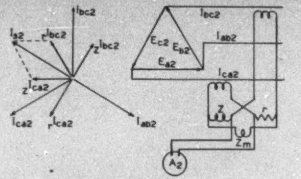


Fig. 5. **Negative sequence current**

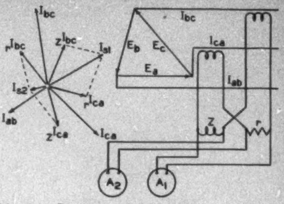


Fig. 6. **Positive and negative sequence current**

current coil of the ammeter. The relations of the impedances are such as to satisfy the equation:

$$z + Z_m = j^{1/3}(r + Z_m) \tag{18}$$

This is the fundamental equation for all the current networks described in this article.

The diagram in Fig. 4 shows a positive sequence network assumed to be applied to a positive sequence set of 3-phase currents. It is apparent, from eq 18 and the diagram, that each of the line currents divides into 2 equal components 60 deg apart. One component passes through the resistance r and leads the line current 30 deg; the other component passes through the impedance z and lags the line current 30 deg. The vector diagram of Fig. 4 shows the components of the line currents. Two components pass through the ammeter; ${}_rI_{ca1}$, a component of I_{ca1}, passing through the resistance r, and ${}_zI_{bc1}$, a component of I_{bc1}, passing through the impedance z. Consequently the ammeter indicates the sum of these 2 currents which is equal to I_{s1}. It is seen from the diagram that the current I_{s1} is equal and opposite to the current I_{ba1}. Consequently it is apparent that this ammeter indicates directly the positive sequence current when the network is applied to a positive sequence system.

Again, assuming a negative sequence system of line currents and a negative sequence network as shown in Fig. 5, it is seen that the 2 components which pass through the ammeter are ${}_zI_{ca2}$, a component of I_{ca2} passing through the impedance z, and ${}_rI_{bc2}$, a component of I_{bc2} passing through the resistance r. The ammeter indicates the sum of these 2 components which is equal to I_{s2}. It is seen from the diagram that I_{s2} is equal and opposite to I_{ab2}. Consequently it is apparent that this ammeter indicates directly the negative sequence current when the network is applied to a negative sequence system.

It has now been shown that these component current networks, if it were possible to apply them to their respective systems, would cause the proper component currents to pass through the respective ammeters. It remains yet to be proved that these same networks will meter the respective components if applied to unbalanced systems. The proof of this is shown in the following equations, and the diagram of Figs. 4, 5, and 6.

$$I_{s1} = \frac{j^{11/3}I_{bc1}}{\sqrt{3}} + \frac{j^{1/3}I_{ca1}}{\sqrt{3}} \tag{19}$$

and

$$\frac{j^{11/3}I_{bc2}}{\sqrt{3}} + \frac{j^{1/3}I_{ca2}}{\sqrt{3}} = 0 \tag{20}$$

Therefore,

$$I_{s1} = \frac{j^{11/3}(I_{bc1} + I_{bc2})}{\sqrt{3}} + \frac{j^{1/3}(I_{ca1} + I_{ca2})}{\sqrt{3}}$$

$$= \frac{j^{11/3}I_{bc} + j^{1/3}I_{ca}}{\sqrt{3}} \tag{21}$$

also

$$I_{s2} = \frac{j^{1/3}I_{bc2}}{\sqrt{3}} + \frac{j^{11/3}I_{ca2}}{\sqrt{3}} \tag{22}$$

and

$$j\frac{^{1/3}I_{bc1}}{\sqrt{3}} + \frac{j^{11/3}I_{ca1}}{\sqrt{3}} = 0 \tag{23}$$

Therefore,

$$I_{s2} = \frac{j^{1/3}(I_{bc2} + I_{bc1})}{\sqrt{3}} + \frac{j^{11/3}(I_{ca2} + I_{ca1})}{\sqrt{3}} = \frac{j^{1/3}I_{bc} + j^{11/3}I_{ca}}{\sqrt{3}} \tag{24}$$

It is apparent in comparing eq 19 with 21, and 22 with 24, that the component networks produce the same result when applied to the unbalanced line currents as if they were applied to their respective component systems.

In Fig. 6 is shown the positive and negative sequence networks of Figs. 4 and 5 combined to meter simultaneously and separately the 2 components of current.

METERING OF SYMMETRICAL COMPONENTS OF POWER

In metering power components of a 3-phase system, standard wattmeters may be used, the current coil of the wattmeter replacing the ammeter and the potential coil replacing the voltmeter. As is the case with the voltmeters, the internal resistance R_m of the wattmeter potential coil is removed, leaving only the negligibly small resistance of the moving element of the wattmeter.

Although it is evident from the previous analysis of potential and current networks that correct absolute values of currents will flow through the coils of the wattmeters, it is not so apparent that the phase relations of these currents will be such that each wattmeter will indicate correctly its component of power. In order to show these phase angles and current values clearly, balanced component systems will again be assumed, and 2 methods of measuring the power of each component system will be shown together with vector diagrams.

An assumed balanced positive sequence system metered by 2 separate methods (*a*) and (*b*), is shown in Fig. 7. Method (*a*) is a well-known standard connection consisting of 2 potential transformers, a standard wattmeter and either one or no current transformer. For the sake of simplicity the power factor is assumed to be 100 per cent. The power indication shown in method (*a*) is $E_{ca1} \times I_{ca1} = \sqrt{3}\, E_1 \times I_1$ positive sequence power. Method (*b*) involves the component network system consisting of a standard wattmeter with its potential internal resistance R_m removed, a positive sequence current network equivalent to that shown in Fig. 4, a positive sequence voltage network equivalent to that shown in Fig. 1 with the exception that the value $K = 1$. A comparison of the 2 vector diagrams of Fig. 7 reveals that the 2 wattmeters will indicate the same values and consequently the correct positive sequence watts.

An assumed balanced negative sequence system, metered by 2 separate methods (*a*) and (*b*) is shown in Fig. 8. Method (*a*), as in Fig. 7, is a standard connection. Method (*b*) involves a component network system, consisting of a standard wattmeter with its potential internal resistance R_m removed, a negative sequence current network equivalent to that of Fig. 5 with the exception that the current transformers are located in different lines, a negative sequence potential network equivalent to that shown in Fig. 2 with the exception that $K = 1$. A comparison of the 2 vector diagrams of Fig. 8 reveals that the 2 wattmeters of this figure will indicate the same, and therefore the total negative sequence power of the system.

It has already been shown that component networks, both current and potential, when applied to an unbalanced system, give the same results as if they were applied to their respective component system. Consequently the networks shown in Figs. 7 (*b*) and 8 (*b*) may be combined as shown in Fig. 9, with the assurance that each wattmeter will indicate its respective component of power. The relative complex values of the impedances for this network are given in the following equations:

$$Z_{c1} = Z_{a2} = Kj^{2/3}R_m \tag{25}$$

$$Z_{a1} = Z_{c2} = Kj^{0}R_m \tag{26}$$

It is important to observe that when $K = 1$ in the networks of Fig. 3 the voltmeter reading is too high by the $\sqrt{3}$ factor, and K is therefore not the multiplying constant of the voltmeter. When these same networks are used however in the measurement of power as in Fig. 9, and $K = 1$, the wattmeters read direct and K is the multiplying factor of the wattmeter assuming a 1 to 1 ratio of instrument transformers.

In order to determine definitely the location and number of instrument transformers to be used in conjunction with the various networks which are shown in this article, numerical values of an unbalanced 3-phase 3-wire system will be assumed, and the component values calculated.

E_a	$100 + j\,0$	I_{ab}	$32 - j\,13.5$
E_c	$-25 + j\,50$	I_{ca}	$-22.35 + j\,15.165$
E_b	$-75 - j\,50$	I_{bc}	$-9.65 - j\,1.665$
E_{a1}	$78.8 - j\,14.45$	I_{ab1}	$20.99 - j\,3.066$
E_{c1}	$-26.88 + j\,75.525$	I_{ca1}	$-7.845 + j\,19.69$
E_{b1}	$-51.92 - j\,61.075$	I_{bc1}	$-13.145 - j\,16.627$
E_{a2}	$21.15 + j\,14.45$	I_{ab2}	$11.002 - j\,10.421$
E_{c2}	$1.93 - j\,25.525$	I_{ca2}	$-14.53 - j\,4.34$
E_{b2}	$-23.09 + j\,11.075$	I_{bc2}	$3.53 + j\,14.76$

Total power	3,048 watts
Positive sequence power	2,596 watts
Negative sequence power	452 watts
Zero sequence power	0 watts

Applying the network of Fig. 9 to the unbalanced set of voltages, complex values of currents may be calculated which pass through the current coils of the wattmeters, and equivalent voltages may be calculated which produce currents through the potential coils of the wattmeters. From these values the indication of the wattmeters may be computed. Table I contains these values for different locations of the instrument transformers. For example, E_{cb1} is the equivalent voltage of wattmeter W_1 when the potential transformers are located across voltages E_c and E_b; and $I_{2(ab)\,(ca)}$ is the current passing through the current coil of wattmeter W_2 when the current transformers are located in lines *ab* and *ca*. Only those combinations may be used which give approximately 2,596 watts in the positive sequence wattmeter and 452 watts in the negative sequence wattmeter. It is

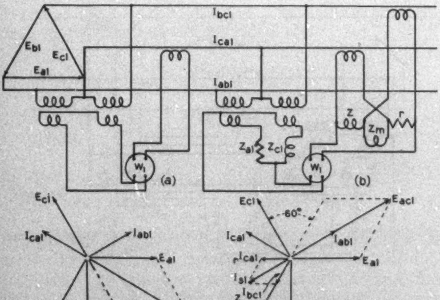


Fig. 7. Positive sequence power

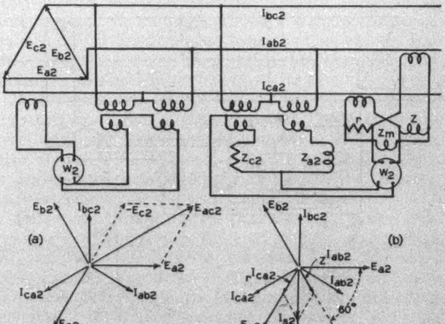


Fig. 8 Negative sequence power

important to notice that 4 current transformers are necessary when using the network of Fig. 9.

The load current network would be greatly simplified if only 2 current transformers could serve both positive and negative sequence networks as in Fig. 6, and yet give the proper phase relations. This is accomplished by a network shown in Fig. 10. The negative sequence potential impedances are the same as those in the network of Fig. 9. The positive sequence potential impedances are changed; one is a pure resistance, the other a condensive impedance.

$$Z_{a1} = Kj^{10/3}R_m \tag{27}$$

$$Z_{c1} = Kj^{0}R_m \tag{28}$$

The vector diagram of Fig. 10 and eqs 27 and 28 show the phase relations of the positive sequence system. Comparing this diagram with that of Fig. 8 (*b*), it is seen that 2 series transformers located in lines *ca* and *ab* will give the proper phase relations for the 2 systems. The simplified network of Fig. 10 therefore will meter simultaneously and separately the 2 components of power. Table II gives the possible combinations of transformers for this network.

POSITIVE AND NEGATIVE SEQUENCE ENERGY

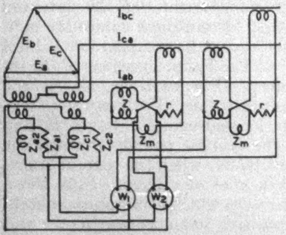
It is apparent that a network which will be operative with electrodynamometer type wattmeters, wherein the high resistance of the potential circuit may be separated from the negligibly small resistance of the moving element, will not be operative in conjunction with induction type watthour meters wherein the highly inductive impedance of the potential coil exists as one inseparable unit.

In Fig. 11 is revealed a network designed to be used with standard induction type watthour meters. The load current network is the same as in Fig. 10. The potential networks have been altered to produce the proper phase relations. X_c is a condensive reactance equal to and placed in series with the inductive reactance X_L of the potential coil of the watthour meter. The relations of impedances in this energy net work are shown in eqs 29 and 30:

$$Z_{a1} = Z_{c2} = Kj^{8/3}X_L \tag{29}$$

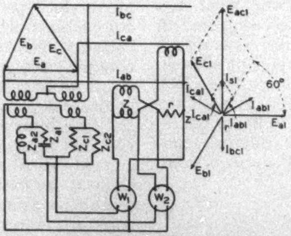
$$Z_{c1} = Z_{a2}Kj^{10/3}X_L \tag{30}$$

In this network as in the network for metering power, the potential coil currents are entirely controlled by the network impedances, since the condensive reactance X_C balances out the effect of the inductive reactance X_L, and the effective resistance of the potential coil is assumed to be negligible. The vector diagrams of Fig. 11 show that when the potential transformers are located across voltages E_a and E_c, and the current transformers are located in lines *bc* and *ab* the watthour meters will register the true components of energy. Table III shows the possible



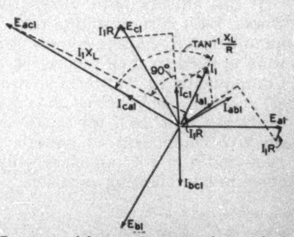
Ibc
Ica
Iab
Eb
Ec
Ea
Za2
Za1
Zc1
Zc2
Z
r
Zm
W1
W2

Fig. 9. Positive and negative sequence power



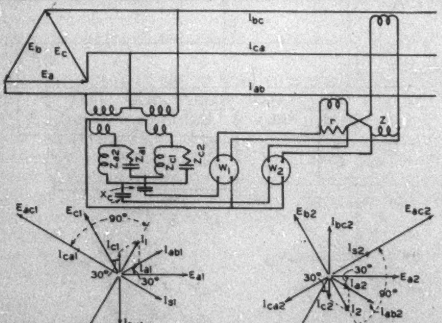
Ibc
Ica
Iab
Eb
Ec
Ea
Za2
Za1
Zc1
Zc2
Z
r
W1
W2
Eac1
Ec1
Is1
60°
Ica1
Iab1
Ea1
Ibc1
Eb1

Fig. 10. Positive and negative sequence power



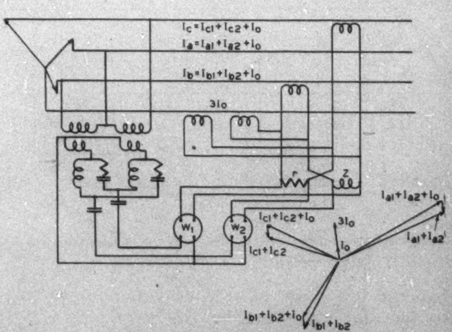
Eac1
I1R
Ec1
I1XL
TAN⁻¹ XL/R
90°
I1
Ic1
Ia1
Ica1
Iab1
Ea1
I1R
Ibc1
Eb1

Fig. 12. Vector diagram of modified energy network



Ibc
Ica
Iab
Eb
Ec
Ea
Za2
Za1
Zc1
Zc2
Xc
r
Z
W1
W2
Eac1
Ec1
90°
Ic1
I1
Iab1
Ica1
30°
Ia1
30°
Ea1
Is1
Eb1
Ibc1
Eb2
Ibc2
Eac2
Is2
30°
30°
Ea2
Ia2
90°
Ica2
Ic2
I2
Iab2
Ec2

Fig. 11. Positive and negative sequence energy



Ic=Ic1+Ic2+Io
Ia=Ia1+Ia2+Io
Ib=Ib1+Ib2+Io
3Io
r
Z
W1
W2
Ic1+Ic2+Io
Ic1+Ic2
3Io
Io
Ia1+Ia2+Io
Ia1+Ia2
Ib1+Ib2+Io
Ib1+Ib2

Fig. 13. Three-phase 4-wire network

combinations of instrument transformers to be used with this network.

In the design of the network of Fig. 11, it was assumed that the effective resistance of the potential coil was small enough to be neglected without appreciable error in the registration. In some watthour meters this resistance may be of sufficient magnitude to cause errors too great to tolerate. A slight modification of the positive sequence impedance values in accordance with the vector diagram of Fig. 12 and eqs 31 and 32 will tend to decrease errors due to the presence of resistance of the potential coil.

$$I_1 = I_{a1} + I_{c1} = \frac{E_{a1} - I_1R}{Z_{a1}} + \frac{E_{c1} - I_1R}{Z_{c1}} = \frac{\sqrt{3}j^{1/3}E_{c1}}{K(R + jX_L)} \qquad (31)$$

$$I_{c1} = j^{2/3}I_{a1} \qquad (32)$$

Table I—Location of Potential and Series Transformers to Meter Simultaneously, Positive and Negative Sequence Power When Using Network Shown in Fig. 9. K = 1

Potential Transformers	Series Transformers	Watts
1. E_{ac1}	$I_1(ca)(bc)$	2,597
E_{ac2}	$I_2(ca)(ab)$	451.6
		3,048.6
2. E_{ab1}	$I_1(ca)(ab)$	2,591
E_{ab2}	$I_2(bc)(ab)$	452.5
		3,043.5
3. E_{cb1}	$I_1(bc)(ab)$	2,599
E_{cb2}	$I_2(ca)(bc)$	454
		3,043

Table II—Location of Potential and Series Transformers to Meter Simultaneously, Positive and Negative Sequence Power When Using Network Shown in Fig. 10. K = 1

Potential Transformers	Series Transformers	Watts
1. E_{ac1}	$I_1(ca)(ab)$	2,591
E_{ac2}	$I_2(ca)(ab)$	451.6
		3,042.6
2. E_{ab1}	$I_1(bc)(ab)$	2,599
E_{ab2}	$I_2(bc)(ab)$	452.5
		3,051.5
3. E_{cb1}	$I_1(ca)(bc)$	2,597
E_{cb2}	$I_2(ca)(bc)$	454
		3,051

METERING OF COMPONENTS OF POWER OR ENERGY IN 3-PHASE 4-WIRE SYSTEMS

Since the fundamental principle of operation of the networks previously described is based on the fact that the 3 unbalanced vectors must add to zero and therefore contain no zero sequence components, it is apparent that the current networks will not function in 3-phase 4-wire systems wherein zero sequence currents may flow. The potential networks, however, will function if line voltages are utilized to feed the network, since they contain no zero sequence components.

A diagram of a network designed to meter positive and negative sequence components of power in the presence of zero sequence currents is shown in Fig. 13. The potential network is similar in all respects to those used in the other circuits previously described. The current network is also similar to the others with the exception that a double secondary current transformer is placed in the fourth conductor. The ratio of transformation of this transformer is 3 times that of the other 2 current transformers. The secondaries are connected in the circuit differentially with respect to the secondaries of the others. This connection causes only the positive and negative sequence components to flow into the network impedances, and the latter functions as in all the other networks.

Table III—Location of Potential and Series Transformers to Meter Simultaneously Positive and Negative Energy (Watthours) When Using Network Shown in Fig. 11. K = 1

Potential Transformers	Series Transformers	Watts
1. E_{ac1}	$I_1(bc)(ab)$	2,599
E_{ac2}	$I_2(bc)(ab)$	452.5
		3,051.5
2. E_{ab1}	$I_1(ca)(bc)$	2,597
E_{ab2}	$I_2(ca)(bc)$	454
		3,051
3. E_{cb1}	$I_1(ca)(ab)$	2,591
E_{cb2}	$I_2(ca)(ab)$	451.6
		3,042.6

Attention is called to the fact that zero sequence currents may be eliminated by another method of connecting 2 differentially connected pairs of series transformers together so that currents equal to the difference of the line currents flow through the network. This method, however, causes currents to flow through the meters equal to $\sqrt{3}$ times their true value and 30 deg displaced from the true values, and therefore would not be suitable for the networks shown in this article.

The vector diagram of Fig. 13 shows an assumed unbalanced current system containing positive, negative, and zero sequence components. The diagram also shows 3 unbalanced currents containing only positive and negative sequence components, the zero sequence components having been removed.

It is important to notice that the total power of a 3-phase 3-wire system is metered by the 2 wattmeters W_1 and W_2. In 3-phase 4-wire systems the total power is the sum of the positive, negative, and zero sequence components, the latter component not being metered. The zero sequence component may be metered by standard instrument transformers and meters involving no network. It is only necessary to use 3 potential transformers and one current transformer connected as shown in Fig. 14.

Zero sequence power-$3E_0I_0 \cos \varphi$ (33)

Positive and Negative Sequence Reactive Volt-Amperes

Although the networks shown in Figs. 10 and 11 were designed primarily to meter, respectively, power and energy components, it is obvious that the reactive volt-ampere components also may be metered. For example, if electrodynamometer type wattmeters are used in Fig. 11 to replace the watthour meters, it is seen from the vector diagrams of this figure that the equivalent voltages E_{ac1} and E_{ac2} will be in phase, respectively, with I_1 and I_2, and consequently in quadrature with I_{s1} and I_{s2}. These are the proper phase relations for metering reactive volt-amperes in a system of 100 per cent power factor which the diagrams represent. The condensive reactances X_C will be omitted in this case. Again, if watthour meters together with proper values of X_C are used to replace electrodynamometer type wattmeters, it is also apparent that the potential coil currents I_1 and I_2 would be in phase, respectively, with I_{s1} and I_{s2}. These are the proper phase relations for metering reactive volt-ampere-hours with watthour meters.

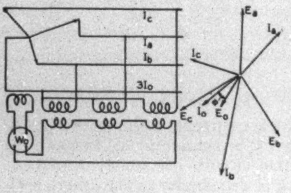


Fig. 14. Zero sequence power

Consequently the networks shown in Figs. 10 and 11 may be designed to meter either the real or reactive components of power and energy.

Conclusion

Since the zero sequence current does not exist in a 3-wire 3-phase system, there is no zero sequence power, and the wattmeters W_1 and W_2 indicate the total watts of the unbalanced system. In 3-wire systems having unbalanced load currents but balanced line voltages, the negative sequence power is zero, and the wattmeter W_1 will indicate the total power of the system. This case will occur when the power is metered directly at the terminals of the alternator the no-load line voltages of which are balanced. The positive sequence wattmeter will also indicate a small negative sequence copper loss. The negative sequence meter will indicate only negative sequence copper loss of the alternator.

Since zero sequence power may exist in a 3-phase 4-wire system, the 2 wattmeters W_1 and W_2 may not meter the total power of the unbalanced system. This is the case when both E_0 and I_0 are present. In systems having balanced voltages E_0 may be equal to zero, and although I_0 is present, the total power of the system is equal to the sum of W_1 and W_2.

As in 3-wire systems, the wattmeter W_1 will indicate the total power of the 4-wire system at the terminals of the alternator, if the no-load voltages are balanced. This suggests the possibility of metering large blocks of power at the alternator terminals with one wattmeter, a positive sequence network, 2 potential transformers, 2 current transformers replacing 3 wattmeters, 3 current transformers and 3 potential transformers.

When a line to line short circuit occurs on a 3-phase system, the negative sequence voltage and the negative sequence power increases from approximately zero at the generator terminals to a maximum at the point of short circuit. On the other hand, the positive sequence voltage and positive sequence power decrease from a maximum at the generator terminals to a minimum at the point of short circuit. Positive and negative sequence components of power might be utilized in relays where definiteness of action depends upon the amount of voltage available at the relay. One relay utilizing the balanced components of current and voltage will function regardless of which phase is short circuited. This fact is a point in favor of an investigation into the possibilities of component current, voltage, and power relays.

It is apparent that a network must be designed for one frequency and will be in error at any other frequency. In large interconnected systems having synchronous timing devices as part of their load, the frequency is not allowed to depart appreciably from 60 cycles, even under short circuit conditions, and metering errors due to this cause would not be serious.

A network similar to that shown in Fig. 10 was constructed in the laboratories of the University of Washington. In tests conducted with correct frequency errors no greater than $2^1/_2$ per cent were recorded. In tests for accuracy with change of frequency; 59 to 61 cycles showed errors no greater than 0.5 per cent; and 55 to 65 cycles showed errors no greater than 4.5 per cent. The various tests conducted as a whole speaks well for the ultimate possible accuracy of such networks when designed and constructed by meter manufacturers, experienced with this type of equipment.

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Lighting for Effective Seeing

A non-technical explanation of the fundamental conceptions and relations underlying the application of lighting for effective seeing is given in this article. The tables and diagrams included should be useful in any study of illumination and intensity.

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THE INFLUENCE of good lighting on seeing has been demonstrated by various laboratory studies; the successful application of the results brought forth in these studies, however, depends upon an understanding of the fundamental principles of lighting and seeing. So far, the maximum economic and human benefits from the manufacturing and technical developments in artificial lighting have not been secured, due to the fact that the fundamental principles are not sufficiently well known. Certain of these principles are outlined in the following paragraphs.

An individual retains a mental picture of each visual observation. Whether that picture is clear and distinct, or is hazy and easily forgotten or easily replaced, depends largely upon whether the light was proper, the lens (or eye) was accurate, and the film (retina and receptiveness) fresh and sensitive, with proper time allowance for good impression. Of these 3 elements in seeing, 2 are suggested in Fig. 1; namely, first, the external physical realm including light and lighting, and second, the eye or visual sense. The third element, the internal realm consisting of the mental processes and resulting physiological and psychological effects, is not included in this figure. It has been said that man can see better than any other animal—because of his intelligence. The problem of proper lighting for seeing is affected by such incidental conditions—the subject's vision, perception, interpretation, and reactions—but these are elements beyond the direct control of the illuminating engineer. It is indeed true that oculists may heal sick eyes and fit crutches to crippled eyes, and educators and experience can train the mind and body to react, but all the oculists and educators in the country cannot make even a normal man see without light. Providing the proper lighting is the job of the engineer, and Fig. 1 indicates some of the characteristics which must be considered.

Among these characteristics of lighting we find certain positive factors such as level of illumination or foot-candles, and distribution and diffusion of the light; certain negative factors such as glare, direct and reflected; and other characteristics, which may be helpful or otherwise, such as direction of light, source brightness, type of object to be seen, and background about that object.

The seriousness of one of the least appreciated of these characteristics, glare, is illustrated by the following example. An operator is working before a machine illuminated by a bare lamp bulb and suspended on a drop cord above the machine. Assuming that seeing conditions other than glare are satisfactory, the seeing ability of the operator will be reduced to 58 per cent if this lamp bulb, the source of glare, is at an angle 40 deg above the line of vision; this simply means that 42 per cent of the light originally furnished is neutralized or rendered ineffective and wasted. As the glare source is lowered further toward the line of vision, its importance as a waster of energy and an interference with seeing greatly increases. At any angle of 20 deg above the line of vision, 53 per cent of the light is wasted, at 10 deg 69 per cent is wasted, and at 5 deg 84 per cent of the light furnished is wasted.

WHAT CONSTITUTES BETTER SEEING?

Let us examine more in detail the results in better seeing through the elimination of glare. Without

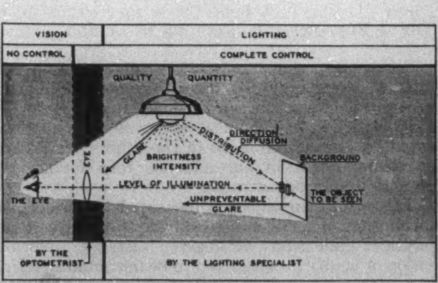

Fig. 1. Lighting and vision are both necessary for seeing

Essentially full text of an address presented before a conference on economics of applied lighting, Case School of Applied Science, Cleveland, Ohio, Feb. 8–9, 1933, and based upon a pamphlet "Lighting for Seeing," by M. Luckiesh (M'15) and F. K. Moss. *Not published in pamphlet form.*

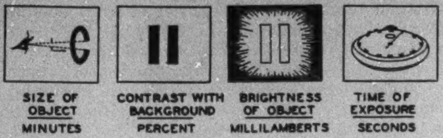
SIZE OF OBJECT
MINUTES
CONTRAST WITH BACKGROUND
PERCENT
BRIGHTNESS OF OBJECT
MILLILAMBERTS
TIME OF EXPOSURE
SECONDS

Fig. 2. The 4 fundamental factors in seeing

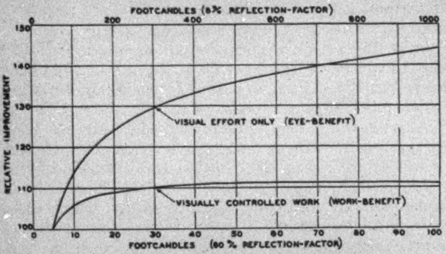

Fig. 3. Relation between performance and brightness

Eye-benefit involves simple visual recognition of test objects. Work-benefit involves performance of various tasks guided by vision

the glare source, and assuming satisfactory general illumination, the subject could see smaller details, such as smaller marks or flaws on the work, finer textures or patterns in various kinds of merchandise, or smaller type in the office or schoolroom. He could also see the same size of details under less favorable contrast conditions, such as would be suggested by a metal scale with the fine markings plain rather than filled, by less contrasting shades of trim on a dress (same colors) or less sharpness of contrast on the printed or written page or blackboard in the office or schoolroom. Given any set of the above conditions, he could see as well with less concentration effort or in a shorter time with the same concentration. A further study of the glare tests establishes that the glare becomes less damaging when the general brightness of the illuminated object is increased in a proper manner, as will be explained later.

THE 4 FUNDAMENTAL FACTORS IN SEEING

Seeing is possible only when all 4 fundamental factors shown in Fig. 2 are above certain limiting values. These factors are so interrelated that usually a deficiency in one or more factors may be counteracted by an augmentation of the others. They are so all-important in our analysis that further explanation may be desirable.

The size of an object is measured by the oculist in minutes of angle subtended, or by most of us in physical dimensions at a given distance. Normal vision or acuity is considered to be one minute, which is equivalent to a $^3/_8$ in. rod at a distance of 100 ft. While the eye evolved under seeing conditions requiring distant vision, usually of large details and incidentally under high intensities, it is required today to observe minute details accurately and quickly and often for long periods of time.

By brightness is meant the light reflected from an object to the eye. We do not see the object, we do not see the light falling upon the object, we do not even see the light reflected from the object in any other direction than toward our eyes, because the eye is merely a measuring instrument to detect and classify the light rays which enter it. Usually our problems involve materials with mat surfaces and general illumination, and the brightness is then largely a matter of foot-candles intensity of illumination times reflection factor. It is very important that we bear this in mind.

In contrast, as here used, differences in color must be eliminated. They are important because of the varying physical and mental reactions stimulated by different colors, and because of their varying reflection factors and therefore brightnesses under similar intensities of illumination, an example of both being found in highway signs. So they have their influence on seeing and must be considered, qualitatively. But it obviously would be impossible to include them in a fundamental quantitative study because of the enormous increase in number of conditions which would have to be taken into account. So we will here consider contrast only as it involves shades of black and white. A jet black mark on an absolutely white paper will have 100 per cent contrast. Dull finished black beads on a black gown or similar white beads on a white gown might represent nearly the other extreme, the beads being seen only because their contour is indicated by more or less slight shadows, or places of varying brightness. Contrast is somewhat under our control in certain cases, through control of illumination.

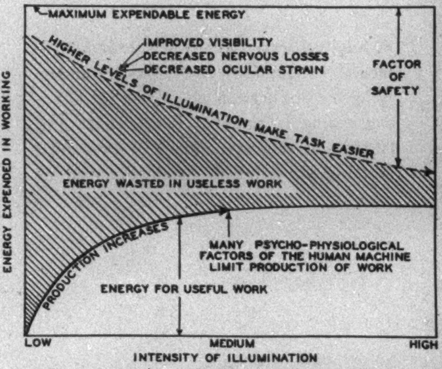
MAXIMUM EXPENDABLE ENERGY
IMPROVED VISIBILITY
DECREASED NERVOUS LOSSES
DECREASED OCULAR STRAIN
HIGHER LEVELS OF ILLUMINATION MAKE TASK EASIER
FACTOR OF SAFETY
ENERGY WASTED IN USELESS WORK
PRODUCTION INCREASES
MANY PSYCHO-PHYSIOLOGICAL FACTORS OF THE HUMAN MACHINE LIMIT PRODUCTION OF WORK
ENERGY FOR USEFUL WORK
ENERGY EXPENDED IN WORKING
LOW
MEDIUM
HIGH
INTENSITY OF ILLUMINATION

Fig. 4. An analysis of useful and useless work and reserve capacity, as affected by intensity of illumination

Time is a condition in seeing which hardly needs discussion as an element; it has been demonstrated so often by so-called "speed of vision" devices and tests that it is generally recognized.

Brightness is the one fundamental variable which is within our control. Given any combination of size, contrast, and time factors, seeing will become more accurate and more satisfactory with increasing brightnesses. This will result directly from increasing intensities of illumination, where reflection factors are fixed. Given undesirable conditions as regards size, or contrast, or unavailable time, and a greater brightness will aid in overcoming the deficiency.

Further important factors, in addition to glare, are the lighting of surroundings, vibration, and frequent changes in intensities as found in looking from place to place on a desk which is lighted only or largely by a desk lamp.

PRACTICAL SIGNIFICANCE OF BRIGHTNESS

The inverse variation of foot-candles and reflection factors for a given brightness is emphasized in Fig. 3, 30 ft-c at 80 per cent reflection factor accomplishing what 300 ft-c at 6 per cent reflection factor can accomplish. This relation is conservative since it does not take into account changes in contrast due to changes in reflection factor. This one new conception alone, the necessary substitution of brightness for foot-candles, promises to revolutionize the practice of illuminating engineering. Many applications of this principle may be found in the lighting of industrial processes, offices, schools, homes, and all places where seeing is important.

Table I—Foot-Candles Required for Reading a Telephone Directory and Good Book Print

	Telephone Directory	Good Book Print
Reflection-factor of paper	57%	80%
Contrast between ink and paper	80%	97%
Brightness required for equal visibility	5.4	2.6
Foot-candles required for threshold visibility	8.8	3.0

Table II—Increase in Rate of Working for Faster Vs. Slower Groups

Foot-Candles Increased		Increase in Rate of Working	
From	To	Faster Group	Slower Group
3	12	28%	40%
6	12	15%	20%
12	48	10%	12%
24	48	5%	6%

Another important idea conveyed by Fig. 3 is that other elements besides seeing may enter into the performance of tasks. The upper curve shows the improvement to be expected from an increasing brightness upon such work as proof reading, involving visual effort, while the lower curve indicates that a point may be reached beyond which other conditions than seeing may determine the results. This lower curve suggests a state of saturation, so far as work-benefit is concerned, but this is not exactly true, as will be shown in the analysis of Fig. 4. We may expect to learn that improvements in lighting may ultimately result beneficially both for employer and for employee, even when carried far beyond the apparent saturation point for any particular task.

The calculated results in one reading case are shown in Table I, which gives the illumination intensities needed for equal ability to see black print on white book paper and dull print on the light grey paper of a telephone directory. The amounts given are those required for threshold visibility for the conditions assumed, including critical details of about one minute visual angle. Since for normal use at least 10 ft-c are needed for comfortable and satisfactory reading from well-printed books, about 30 ft-c should be available for reading tasks such as are represented by the directory.

"Threshold visibility" or border-line seeing denotes to the oculist the point at which the subject sees accurately more times than inaccurately. In the laboratory it was necessary to locate threshold visibility much more accurately than could be done with the Snellen chart used by the oculists.

IMPROVED LIGHTING HELPS WEAK SUBJECTS MOST

It is interesting to learn that those people who benefit most from improved lighting are those who are naturally slow and whose eyesight is impaired, thus most needing the benefit. The production results indicated in Table II not only show that an increase in the rate of working may be expected for any appreciable improvement in lighting intensity, but that the slower group gains more than does the faster group. Another group of tests, taken with 2 groups, one having better than average eyes and the other having worse than average, showed that for an equal increase in lighting intensity, the group with better eyes increased their rate of working 14 per cent, while the group with the poorer eyes increased their rate 22 per cent. Defective vision is very common, as indicated by Table III. These figures show the necessity for proper lighting conditions.

An indication of what improved lighting can do for defective eyes is indicated in Table IV, which includes only the factor of increasing the illumination

Table III—Prevalence of Defective Vision

By Groups	Per Cent Defective	Per Cent Corrected	Per Cent Uncorrected
Public schools	22	13	9
Colleges	40	18	22
Industries	44	19	25

	Under					Over
By Ages	20	30	40	50	60	60
Per cent defective	23	39	48	71	82	95

intensity. This table indicates that additional light improves seeing over one-half as much as does the wearing of eyeglasses. In this test, the benefit of increased illumination was measured with the eyes aided by glasses.

HOW MUCH INCREASE IN INTENSITY?

An increase in intensity from 1 to 100 ft-c is indicated in Table IV. At present, most users are unwilling to install 100 ft-c, and Table V is of assistance in determining the values of increase in illumination intensity which results in the greatest benefit. In this table it is assumed that the raising of the intensity from any initial value to 100 ft-c gives an improvement in seeing which is designated as 100 per cent. From this table it may be seen that increasing the intensity from 4 to 8 ft-c will give 31 per cent of the improvement secured by increasing to 100 ft-c. Also, increasing the intensity from 8 to 16 ft-c gives 37 per cent improvement. Increasing from 8 to 12 ft-c is found to give only 23 per cent improvement as compared with the 31 per cent when increasing from 4 to 8 ft-c.

This indicates 2 things: First, that a substantial improvement in seeing will result from a partial step toward what may be the ideal intensity; but second, that the improvement is not the same for the same additional amount of foot-candles with different initial values. The second is perhaps the more significant. The minimum steps in lighting intensity, given in foot-candles, required to produce an obvious and significant improvement in seeing are as follows:

1 2 5 10 20 50 100

These minimum steps take into account such factors as production, comfort, and eyesight conservation.

ENERGY EXPENDED IN SEEING

Thus far, particular emphasis has been laid upon the physical factors suggested in Fig. 1, and we have largely stopped at the eye. However, even the work-benefit curve in Fig. 3 depends upon light plus sight and then upon perception, recognition, interpretation, reaction, decision, and action. A tremendous amount of human or nervous energy is consumed in seeing alone, and wasting or conserving this energy must have some effect on the rest of the body. A probable allotment of energy expended in performing a visual task, whether useful or not is suggested in Fig. 4. This diagram, first prepared as the result of incidental observations, has remained to be verified, at least in part, by actual tests.

Table IV—Improvement in Seeing Due to Eyeglasses and Due to More Light

Effect of Optical Correction			Effect of More Light		
	Minimum Size of Object Visible			Minimum Size of Object Visible	
Subject	Without Glasses	With Glasses	Subject	1 Foot-Candle	100 Foot-Candles
A	2.50′	*0.75′	A	0.98′	*0.61′
B	1.50′	0.75′	B	1.10′	0.63′

*These values are not identical since measurements on vision, with and without glasses, were made with the test-card of the ophthalmologist which is not graded in fine steps of size.

A practical interpretation of this diagram is that when there is very little light, very little useful work can be performed and a great deal of energy must be wasted in the effort, the proportion which these 2 combined bear to the maximum expendable energy depending upon the urgency of or interest in the task. As the lighting intensity increases, it is possible to do more useful work and the total effort, even to do this greater amount, is less than before, leaving a greater factor of safety or reserve capacity untouched. Thus a Chicago lithographic plant found it impractical to work overtime more than 3 evenings a week, whatever the urgency of the job, because of the deleterious effect upon the work on the fourth day. Then a high-intensity good-quality lighting installation was made, and the men could work overtime every night in the week, if need be, without undue fatigue.

Table V—Rates of Improvement in Seeing With Increases in Illumination Intensity

Initial Foot-Candles		New Levels of Illumination (ft-c) and Per Cent of Possible Improvements in Seeing					
4	(ft-c)	6	8	10	12	16	20
	(%)	19	31	40	47	57	64
8	(ft-c)	12	16	20	24	32	40
	(%)	23	37	48	54	65	73
12	(ft-c)	18	24	30	36	48	60
	(%)	26	41	52	61	74	82
16	(ft-c)	24	32	40	48	64	80
	(%)	27	45	57	68	81	91
20	(ft-c)	30	40	50	60	80	100
	(%)	28	49	64	74	89	100

The most fascinating thing about this chart is the continued slope downward of the total energy curve, even though the useful energy curve seems to have passed the apparent "saturation" point previously referred to. Thus 50 ft-c may mark the limit beyond which no further immediate work benefit will appear, but 200 ft-c may result in an ease of working which will conserve energy for emergencies and assure continuous high efficiency operation.

In most cases, the applications of these scientific relations must still be qualitative—the conditions cannot usually be determined accurately enough in the field to make specific calculations. But that is true of most scientific facts; we have more or less precise quantitative data available under laboratory conditions and, depending upon a knowledge of this data and of the conditions in the problem, and protected by such factors of safety as judgment dictates, a satisfactory solution is secured. We may, at least, now advance much more definitely and confidently into a new environment of improved lighting standards.

An Analysis of Hydro-Regeneration

Use of the regnerative cycle at hydroelectric plants with available pondage will increase the firm peak capacity of electric power systems having both steam and hydroelectric stations. Principles underlying this method as well as empirical results from laboratory and field tests are given in this article, including an analysis of factors limiting its field of application. This supplements the article "Economic Aspects of Water Power" published in the December 1932 issue of ELECTRICAL ENGINEERING, p. 846–52.

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STORING water by pumping it into specially constructed reservoirs for the purpose of producing peak power, was started over 30 years ago. Compared with electric storage batteries or the storage of energy in heat or pressure accumulators, the pumped storage of water shows greater flexibility and is more economical per unit of stored energy, although the efficiency of conversion is lower than that of other means of storing energy.

Maximum over-all efficiency of a pumped storage plant in which each part is designed to do its respective duty in the most efficient manner is approximately 65 per cent. Pumping efficiencies of approximately 60 per cent can be obtained by operating in reverse direction, but at the same speed and head, certain types of turbine runners which originally were designed to function only as waterwheels. If such machines be used for pumping instead of separate specially designed pumps having average efficiencies of about 85 per cent, the over-all efficiency of conversion is reduced to about 45 per cent.

As the 3-phase generator can be readily adapted for reverse operation as a motor merely by interchanging 2 armature leads, the dual use of turbine runner and generator as motor-driven pump will entail only a negligible investment to accomplish the purpose of regeneration. However, if operating conditions be such that the regenerative cycle normally must be repeated every day, the lowering of the over-all conversion efficiency will amount to an appreciable sum in an average year, probably sufficient in many plants to overbalance the possible saving in investment.

At pondage equipped run-of-river plants, that have a pronounced low-flow stage, corresponding approximately to the flow duration curve shown in Fig. 1, the number of days on which operation under the regenerative cycle is necessary will be relatively small and the loss of efficiency due to the use of the turbine unit as a pump instead of a specially designed pumping unit will not be such an important factor. Necessity for the regenerative cycle will arise probably only in the event of coincidence of heavy load demands, minimum flow, and outage of steam reserves on the load system served by the hydroelectric plants. The increased energy consumption due to the lower efficiency need not be viewed therefore as a continual operating expense, but it will be of the utmost importance to establish beyond doubt that the dual use equipment can perform the full duty expected of it for the purpose of firming a certain amount of installed hydroelectric capacity. This phase of the problem is dealt with later in this article. In the following paragraphs the approximate amount of additional hydro capacity that may be installed at low increment cost in excess of that capacity which is rendered firm on the system load by the minimum

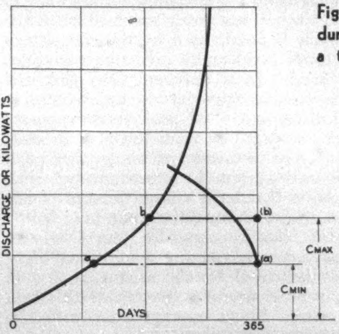


Fig. 1. Flow duration curve for a typical stream

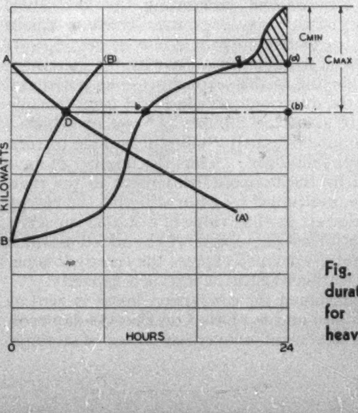


Fig. 2. Load duration curve for a typical heavy-load day

Full text of the appendix to "Economic Aspects of Water Power" (No. 32-128) presented at the A.I.E.E. Middle Eastern District meeting, Baltimore, Md., Oct. 10–13, 1932.

natural inflow will be determined for a typical example.

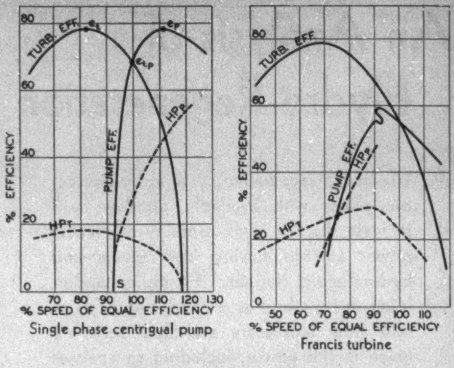
Load for a typical heavy-load day as shown in Fig. 2 is assumed to be supplied normally by a combined water power-steam system of which water power furnishes at times of minimum regulated river flow a load corresponding to the cross-hatched upper portion of the load area. The corresponding amount of water power capacity rendering firm peak service to this load system is represented by *C min*. The area to the left of the curve will be called the no-load area.

The integrated load area below the horizontal line *a*(*a*) is plotted at a suitable scale as a curve starting at point *A* in such a manner that the abscissa of any point along the curve *A*(*A*) represents the load area lying above a horizontal line through that point and below line *a*(*a*). From point *B*, which corresponds to the minimum load of the load duration curve, a curve *B*(*B*) is drawn any abscissa of which represents the integration of the no-load area below a horizontal line through the selected point multiplied by the over-all efficiency of conversion. A horizontal line drawn through the point of intersection *D* of these 2 curves will divide the load curve into an upper area indicating the load that can be supplied by water power produced by natural inflow as well as by regenerative cycle, and into a lower area in which the steam plants will operate at 100 per cent load factor.

In the foregoing it has been assumed that the regenerative cycle is not limited by the capacity of the upper or lower pond or by excessive variations in operating head. It is apparent also that the installed hydroelectric capacity is approximately equal to the full amount of off-peak steam capacity available. A somewhat larger amount of hydroelectric capacity may be installed and render firm peak service if the load system is interconnected with other steam plants that have a large amount of off-peak steam energy available during pumping hours.

Increasing the installed capacity from *C min* to *C max* will yield a certain amount of additional high-flow energy as indicated by the area *a*(*a*) (*b*)*b* in Fig. 1. It may be of interest to compare this gain in high-flow energy in an average year with the energy consumed as conversion loss in the regenerative cycle. Instead of integrating the load areas lying between 2 capacity lines, it is more convenient to compare the increment gain in output per kilowatt for any value of installed capacity with the increment loss corresponding to that capacity. The horizontal distance of the duration curve in Fig. 1 from the 365-day ordinate gives the number of days on which a certain amount of capacity will still be able to turn out full output for 24 hr. Thus the number of days represented by the horizontal intercept to the right of the curve, multiplied by 24 hr will give the energy yield per kilowatt at that value of installed capacity. An incremental loss curve now will be added in which horizontal intercepts also express the energy loss per kilowatt at various values of installed capacity.

Energy consumed for conversion losses is zero at the point *C min* and is plotted on the 365-day ordinate. The increment conversion losses of a single day corresponding to an installed and firmed capacity of *C max* will be equal to the distance (*b*)*b* indicated in the load duration curve of Fig. 2, multiplied by the coefficient (1.0 − conversion efficiency) ÷ conversion efficiency. The number of days on which such increment conversion loss is incurred can be determined from the flow duration curve of Fig. 1 by converting the whole load area in Fig. 2 by the hydroelectric capacity *C max* into 24-hr load at 100 per cent load factor, entering this average load on the duration curve in Fig. 1 and reading the number of days of deficiency at that point. This number of deficiency days is computed to the same scale as the duration curve by multiplying by the incremental loss divided by 24, and is plotted to the left from the 365-day ordinate. The point of intersection of the flow duration curve with the incremental loss curve will indicate the amount of capacity installation beyond which the high-flow energy gains will be exceeded by the conversion losses in an average river year, assuming, of course, that, during the entire period of low-flow, firm peak service to the extent of installed hydroelectric capacity must be produced by the combined effect of natural inflow and regenerative cycle without any assistance whatever from steam reserves.



Single phase centrigual pump

Francis turbine

Figs. 3 (left) and 4 (right). Turbine and pump characteristics of 2 machines

CHARACTERISTICS OF MACHINES FOR DUAL USE

One of the best known means of converting pressure into velocity and back again into pressure is by use of the venturi meter. Its over-all efficiency of conversion is very high. Care is taken in the design so that the flowing water is accelerated and retarded with an almost negligible loss of energy. Such ideal conditions, of course, cannot be duplicated in a waterwheel with its serial arrangement of stationary and rotating water passages involving sharp changes in velocity and direction of flow. Under those conditions efficiencies in excess of 90 per cent are quite an achievement. A high rate of acceleration is possible without disturbing the continuity of flow, permitting a compact design, short water passages, and a minimum of wetted surface and friction; but retardation of water, i. e., conversion of velocity into head cannot be accomplished at as high a rate as acceleration without disturbing the continuity of flow and thereby causing turbulence and shock losses. Energy conversion in a centrifugal pump, therefore, cannot be carried out at as high a rate of efficiency as in the turbine, because water passages must be designed for a more gradual rate of diffusion, which requires a larger amount of wetted surface and greater friction loss. The best efficiencies ever reached by centrifugal pumps are between 85 and 89 per cent. Although apparently only 5 per cent less than best turbine efficiencies, yet, this difference in terms of losses means that the best pump has from 50 to 75 per cent greater losses than the best turbine.

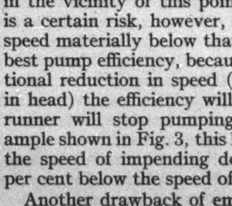
A centrifugal pump that has its best efficiency under certain conditions of head, speed, and discharge for which it is designed, can be made to function as a turbine at the same head and will show the same efficiency, though at reduced speed and discharge. Characteristic curves obtained from tests on a single-stage, 125-hp circulating pump are shown in Fig. 3. The efficiency curves intersect at a point about 10 per cent below that of best efficiency. For an installation where the hours of pumping and of generation are approximately equal, synchronous speed of normal operation for this type of runner should be in the vicinity of this point of intersection. There is a certain risk, however, in lowering the operating speed materially below that at which the runner has best pump efficiency, because with only a small additional reduction in speed (or an equivalent increase in head) the efficiency will drop off rapidly and the runner will stop pumping altogether. In the example shown in Fig. 3, this latter point, usually called the speed of impending delivery, lies only about 7 per cent below the speed of equal efficiency.

Another drawback of employing this type of runner for dual use is indicated by the relation of horsepower input for pumping, to horsepower output for generation. At best, a runner of the characteristics shown in Fig. 3 may be considered for dual use operation only under certain special conditions where the hours of pumping under average conditions will greatly exceed the hours of generation. For example, at some of the existing seasonal pumped storage plants, a motor pump set may be used as a generator at from 25 to 50 per cent of its rated motor input, and at an efficiency of about 50 per cent on some rare occasions of sharp seasonal peaks of short duration. It will contribute whatever turbine output it is capable of, as so much additional firm peak capacity to the system at practically no additional cost.

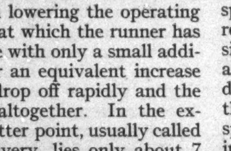
That the modern type Francis runner with its short and sharply reduced and warped water passages is not well suited for regenerative operation, is illustrated by the characteristic curves of such a runner shown in Fig. 4. While the maximum efficiency of this turbine runner appears no higher than that of the centrifugal pump shown in Fig. 3, it should be borne in mind that Fig. 4 gives the test results on a small model, whereas the values of Fig. 3 were obtained from a full-sized installation. Normal synchronous speed of a modern high-specific-speed Francis runner lies usually in a range somewhat below the speed of impending delivery when operating as a pump against the same head. This type of runner cannot be employed for pumping at synchronous speed except in some rare cases where an abnormally large overlap of head between serial plants on the same river permits large fluctuations in operating head, or at storage reservoirs having an unusually large drawdown. However, if coupled with either dual or variable-speed generators, the modern Francis runner has some distinct possibilities for regeneration.

Tests on this type of runner covered a wide range of conditions as to speed, head, gate opening, etc., in combination with 3 types of draft tubes: elbow, spiral, and straight conical. Some of these test results are given in Figs. 5 and 6. There was a considerable spread in the speed of impending delivery as well as in the speed of best pump efficiency for the different types of draft tubes. With the elbow tube, the runner commences to pump at a much lower speed than with the conical tube. Maximum pumping efficiency with the elbow tube was somewhat lower than with the other types of tubes, but at a lower range of speed. Reduced gate openings have the effect of materially lowering the speed of impending delivery for all types of draft tubes.

There is some reasonable expectation that the Francis runner eventually can be developed for dual use at synchronous speed, especially at medium-head installations, if certain modifications are made in the design without appreciably increasing the cost of equipment or lowering the turbine efficiency. One of these requirements is that peripheral velocity be raised slightly above the $\sqrt{2gh}$ value corresponding to the highest expected pumping head h; changes in cross-sectional area of water passages have to be



Curves for various gate openings



Curves for different draft tubes

Figs. 5 (left) and 6 (center). Speed of impending delivery for a Francis turbine

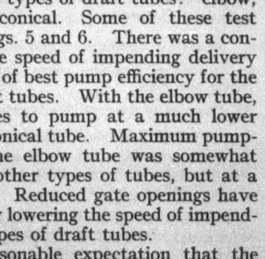


Fig. 7 (right). Turbine and pump characteristics for an adjustable blade propeller turbine

more gradual, the design then leaning toward fewer, but longer blades; such runners probably will be designed for lower specific speed, the ratio of axial length to diameter more nearly approaching that of the older Francis runners.

Among the various types of turbine and pump rotors now available which are designed primarily for a single function, i. e., either generation or pumping, the propeller turbine, and especially the Kaplan adjustable blade type, seem to offer the greatest flexibility for dual use in the regenerative cycle. Figure 7 shows the efficiency curves of a 16-in. model over a range of 60 to 130 per cent of rated turbine head. Over this whole range of operation, the efficiency of the model drops only slightly below 60 per cent, the maximum being 65 per cent. The test results were obtained in the low-head laboratory. Although these efficiencies checked very closely with the test results in the high-head laboratory, certain practical limitations were set by cavitation. At operating heads below 50 ft this probably will not be a serious drawback, especially if serial plants on the same river are laid out with a substantial overlap of head.

AVAILABLE PONDAGE A LIMITING FACTOR

Certain features influencing the extent to which hydroelectric regeneration will be economic have been referred to in the preceding portion of this article as follows:

1. Relation of deficiencies in flow to duration of high-flow stages.
2 Amount of pumping power and number of pumping hours during each cycle.
3. Efficiency of regenerative conversion.
4. Overlap of head and cavitation limit.
5. Relation of increment cost of additional hydroelectric capacity including transmission and tie-in investment, to increment cost of steam capacity.

Aside from the above considerations, any one of which may control the upper limit at which regeneration ceases to be profitable, there is one additional factor that in many instances will set a definite limit on the regenerative cycle, namely, the amount of pondage available.

The ideal condition would be the presence of 2 large lakes, which contain in the first foot or so of storage such a large volume that many times the minimum natural inflow can be shifted every day from the upper to the lower level and back again without any appreciable drawdown in the upper, or rise in the lower level. This ideal condition rarely is found; usually there is an inequality in the 2 ponds, the smaller one of which, of course, will establish the limit for the regenerative cycle. As this question of pond limitation is of some importance, an approximately formula will be developed for the purpose of establishing a relationship between the energy obtainable by pondage under draw-down conditions and the theoretical energy obtainable by the same amount of water if both ponds were of unlimited capacity.

Water discharged into a lower pond in excess of the natural inflow will cause a lowering of the water level in the upper pond and a rise in the lower pond. The drop in the upper plus the rise in the lower pond represents the reduction in head, under which the upper plant will operate at the end of the draw-down period. The lower plant will operate during the whole draw-down period at a gradually increasing head, the maximum at the end of the draw-down period being equal to normal operating head plus the maximum rise in the lower pond. Thus, there will be on the average a lowering in the combined effective operating head of the 2 plants, i. e., a reduction in output from natural inflow alone, below that obtainable from the same water under normal head conditions.

Assuming that there will be no physical limitations, other than those controlled by practical operating conditions, along the shores of the lower pool (railroads, highways, or buildings) or at the power house structure itself, it is reasonable to expect that the excess draw-down may be carried to a point where either an excessive lowering of head renders turbine operation at the upper plant too inefficient or impractical, or where the increased capacity at the lower plant would overload the generators. The limit probably will be reached first at the upper plant and approximately at that head which is the capacity-controlling one at times of very high flood stages.

This maximum reduction of head has been assumed at approximately 40 per cent. Instead of expressing pondage, useful for regeneration, in absolute terms of million cubic feet or in cubic feet per second average flow during 24 hr, it will be expressed in relation to minimum natural inflow, calling the ratio between the two X, which ratio will be shown to have a bearing on the net gain of energy that can be secured over a wide range of pond ratios, i. e., relation of upper pond area to lower pond area.

This net gain N in the kilowatt-hours is independent of the head at the lower plant. It may be expressed in the following general equation

$$N = f_n h_1 \left[X - \frac{XY}{2} - \frac{Y}{2} \right] + f_n \frac{d_2}{2}$$

in which

f_n = kilowatt-hours during 24 hr of minimum natural inflow at 1-ft head.
h_1 = normal head at upper plant.
$f_n h_1$ = kilowatt-hours during 24 hr of minimum natural inflow at normal head of upper plant.
X = ratio of usable pondage to natural inflow.
Y = ratio of upper level drawdown d_1 plus lower level rise d_2 to normal head at upper plant.
d_2 = maximum rise at lower pond.

For a maximum practical Y of 40 per cent and different ratios of X from 1 to 5 and 3 assumed pond ratios (unlimited upper pond, both ponds of same characteristics, lower pond unlimited) this equation will lead to the following coefficients of net gain, i. e., relation of kilowatt-hours obtainable by pondage under draw-down conditions, to kilowatt-hours obtainable by the same amount of water if both ponds were of unlimited capacity:

	X = 1	2	5
Unlimited upper pond.........	80	80	80
Upper and lower pond identical	70	75	78
Unlimited lower pond.........	60	70	76

Some Factors Affecting Inductive Coordination

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Fundamental considerations governing the coordination of power and communication facilities are presented in this article with particular regard to inductive coupling and power circuit influence. Various factors which must be considered are outlined concisely.

INDUCTIVE coordination is one of the most fascinating subjects in electrical engineering. The solution of the numerous problems of inductive coordination is of mutual interest to the power and telephone industries, and involves many phases of electrical engineering. Knowledge and appreciation of the factors involved is necessary for the proper analysis of inductive coordination. Following is an outline of the most important of these factors.

INDUCTIVE EFFECTS

Communication circuits which are located in close proximity to power circuits may absorb relatively small quantities of energy from the power circuits by induction and these extraneous potentials or currents may cause noise or other disturbances in the communication circuits.

The inductive effect which may be experienced is a function of:

1. The inductive influence of the power system.
2. The inductive coupling between the 2 systems.
3. The inductive susceptiveness of the communication system.

Inductive influence refers to the character and intensity of the inductive field due to the characteristics of a supply circuit and its associated apparatus. Inductive influence thus refers to the source of the induced voltage or current and depends upon its magnitude, frequency, system connections, etc.

The inductive coupling is a function of the physical relation between the communication circuits and the power circuits. The coupling for residual ground currents is considerably greater than the coupling for balanced components since the return path of the ground current may be a considerable distance below the surface of the earth.

Inductive susceptiveness refers to the properties of the communication circuit and its associated apparatus to be adversely affected by external electrostatic or electromagnetic fields. The susceptiveness thus depends upon the type and sensitivity of the communication circuit and its condition with particular regard to balance between circuits and to ground, and balance with respect to the paralleling power circuits.

The magnitude of the resultant inductive effect is proportional to the product of *susceptiveness* × *coupling* × *influence*. Inductive coordination is the control of these factors for the purpose of securing good service economically.

ELECTROMAGNETIC VS. ELECTROSTATIC INDUCTION

Voltages may be induced in communication circuits by either electromagnetic (current) or electrostatic (voltage) induction. Electromagnetic induction may be caused by the magnetic field set up by the flow of current in the power wires, or in the wires and returning through the ground. Electrostatic induction may result from the communication circuit being in the electrostatic field set up by the potential between the power circuit wires or between the wires and ground.

Normally, both electromagnetic and electrostatic inductive effects are present. Electrostatic induction is usually of minor importance as compared to electromagnetic induction, due to the considerably smaller magnitude of energy transfer; however, it may possibly be significant in certain cases of normal induction. Electromagnetic induction due to the flow of residual current between the power circuit wires and ground is of prime importance since it gives induced voltages of considerably greater magnitude than electromagnetic induction due to the flow of balanced current components in the power wires themselves.

BALANCED AND RESIDUAL COMPONENTS

The voltages and currents of a power system may be divided into 2 classes of components which are essentially different in their behavior. One class known as balanced components may be divided into systems which are equal in magnitude in each line and have such phase relations that their vector sum is equal to zero at any instant. In a 3-phase system, these components have a 120-deg phase relation and their inductive effects practically neutralize each other. If the system is balanced, they act to produce currents in the line conductors only.

The second class known as residual or zero sequence components are unbalanced with respect to earth as a neutral conductor. The residual components of the line-to-neutral voltage or of the phase currents of a 3-phase system are in the same phase sense and are thus cumulative. Residuals cause

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Based upon a paper presented at a joint meeting of the foreign systems coordination committee and the overhead systems committee of the National Electric Light Association, Columbus, Ohio, March 25, 1932.

considerably more induction than balanced components, since they constitute unbalances with respect to ground.

TRIPLE VS. NON-TRIPLE HARMONICS

The harmonics of the line-to-neutral voltages and phase currents of a power system may be divided into 2 groups. One group consists of the triple harmonics (odd multiples of 3) 3, 9, 15, etc., corresponding to 180, 540, and 900 cycles, respectively, on a 60-cycle system. These triple harmonics form residual components of either voltage or current.

The second group consists of the non-triple harmonics (odd, and not multiples of 3) 5, 7, 11, etc., corresponding to 300, 420, and 660 cycles, respectively, on a 60-cycle system. These non-triple harmonics are essentially balanced components. However, if unbalances (such, for example, as single-phase branches) exist in the power system, the balanced components will act on such unbalances to produce residual components, the effect of which on a telephone line may be more important than the balanced components themselves.

POWER SYSTEM INFLUENCE—LOW FREQUENCY

Under normal balanced conditions on a 3-phase power system, the resulting induced potential is usually small. Under abnormal conditions, however, such as faults to ground, a residual or unbalanced current of considerable magnitude may flow through the ground and cause an appreciable induced potential. The magnitude of the power system currents which may flow under fault conditions, depends upon the characteristics and impedance of the system and may vary from a few amperes to several thousand amperes, depending upon the particular conditions involved.

Fault Conditions. During line-to-line fault conditions on a power system, the fault currents are confined to the power wires, and any resulting inductive effects are generally due to electromagnetic induction from balanced components. During line-to-ground faults on a grounded neutral system, a residual current flows from the point of fault back through the ground to the grounding point. In the case of a ground fault on an isolated neutral system, the residual current consists entirely of charging current to ground. Such currents may cause electromagnetic induction from residual components.

Another possibility is for 2 simultaneous faults to occur on different phase wires of an isolated neutral system at separate locations. Under such conditions the fault current will pass through the ground between the points of fault, and this may cause electromagnetic induction due to the flow of residual ground current.

Relaying. Protective relays are customarily provided on power circuits to isolate such circuits automatically when they develop trouble. These relays operate very quickly and the faulted circuit is cleared by the opening of oil circuit breakers. The time for clearing such faults will vary from a fraction of a second to several seconds, depending upon the type of fault, the protection provided, and the characteristics of the power system.

POWER SYSTEM INFLUENCE—NOISE FREQUENCY

The effect of a current or voltage in producing noise in a communication system is dependent upon its frequency as well as upon its magnitude. The maximum audible range of speech lies between the limits of 50 to 15,000 cycles per sec. Commercial telephone circuits, however, transmit only a much narrower range. The maximum sensitivity of the average human ear and of telephone receivers occurs at approximately 1,100 cycles. Thus currents or voltages having frequencies of the order of 1,100 cycles, such as the 15th, 17th, 19th, and 21st harmonics of a 60-cycle system will cause a maximum noise effect in telephone circuits. These effects may become serious when the rate of energy transfer is appreciable as compared to the power required for the transmission of signals or voice currents over the communication circuits. Therefore, the presence of higher harmonics even of relatively small magnitude in the voltage waves of power systems may cause noise in telephone circuits since the higher harmonics cover a considerable portion of the range of frequency of human speech.

Rotating Machines. An effort is made, in designing rotating electrical appratus, to eliminate the higher triple harmonics and to keep the magnitude of the other harmonics as low as possible. However, harmonics are practically always present in the voltage waves of a-c generators, since it is impossible to obtain a perfect sine wave distribution of magnetic flux and since the slots introduce irregularities in the air gap.

This phase of the subject is very active at this time and a recent survey of wave shapes conducted by the joint subcommittee on development and research, of the National Electric Light Association and the Bell System, showed that the larger steam driven generators generally have somewhat smaller average harmonic voltages and telephone interference factors than hydroelectric machines or steam driven generators of low voltage and small capacity. The measurements indicate that the triple harmonic phase-to-neutral voltages present in $^2/_3$-coil pitch generators are very small compared to those generated in machines having other coil pitches.

Transformer Exciting Current. The exciting current of the magnetic circuit of a transformer will contain harmonics such as the 3rd, 5th, and 7th, since the saturation curve is not a straight line. These currents will be superposed on the 60-cycle fundamental wave if the circuit will permit their flow. If the circuit impedance is high, the deficiency will show up as harmonics in the voltage wave. The magnitude of these harmonics depend upon the saturation of the iron, and a small increase in flux density at saturation will result in a large distortion of the wave. Therefore, transformers operated at over-excitation (above normal rated voltage) may give appreciable harmonics.

Residual Circulating Current. Residual circulating current at fundamental, as well as at harmonic, frequency may occur where the neutral is grounded at more than one point. Transformer banks having delta-connected secondaries or tertiary windings will supply nearly all the third harmonic magnetizing current required for their own wye winding, and also for grounded wye windings of other transformer banks if its own wye winding is grounded, and may thus cause inductive effects due to the flow of stray harmonic current from other parts of the system.

Transmission Circuits. The previously mentioned survey of the wave shape of a number of operating power systems indicated that the average magnitudes of balanced non-triple harmonic currents are approximately the same for all types of circuits. At any given harmonic frequency the average magnitudes of the balanced voltages are approximately proportional to the operating voltages of the circuits, but generally independent of the type of connections employed.

However, the magnitudes of the triple harmonic voltages and currents, which appear as residuals, depend upon whether the transmission circuit is supplied directly by a generator or through transformers, and upon the type of transformer connections at each end of the line. These residual components may be of importance in cases where the transmission circuit is supplied directly (without transformers) or through wye-wye connected transformers with grounded neutral by a generator operating with grounded neutral, and where the transmission line offers a relatively low impedance path to one or more triple harmonics produced by the generator.

Transpositions. Transpositions in a circuit interchange the positions occupied by its conductors. Each wire is made to occupy each position with respect to the others for equal distances, and this tends to neutralize any differences between wires. Transpositions thus assist in obtaining balance in power and communication circuits with respect to each other and to paralleling circuits.

Table I—Effect of Transpositions

Source of Induction in Power System	Component of Induction in Communication System	Effects of Transpositions in	
		Communication System	Power System
Magnetic Induction			
Residual current	Metallic circuit current	Yes	No
Residual current	Longitudinal circuit current	No	No
Balanced current	Metallic circuit current	Yes	Yes*
Balanced current	Longitudinal circuit current	No	Yes
Electrostatic Induction			
Residual voltage	Metallic circuit voltage	Yes	No
Residual voltage	Longitudinal circuit voltage	No	No
Balanced voltage	Metallic circuit voltage	Yes	Yes*
Balanced voltage	Longitudinal circuit voltage	No	Yes

* Power transpositions will reduce metallic noise on untransposed telephone lines. With telephone lines transposed, the effects of power transpositions on metallic noise due to direct induction may be small.

The effect of transpositions is indicated in a general way in Table I. In this table, the balanced and residual components of induction in the communication system are referred to as metallic and longitudinal circuit components, respectively. The longitudinal circuit consists of the line conductors in parallel and with earth return. The potential induced in series with this circuit and the current flowing therein are termed, respectively, longitudinal circuit voltage and longitudinal circuit current. Noise induction in the longitudinal circuit is of interest only as it acts on telephone circuit unbalances to produce effects in the metallic circuit.

Power circuit transpositions have no effect on the induction from residual currents or voltages, except as they may tend to reduce residuals caused by unbalanced capacitances inherent in the power line configuration. Furthermore, the magnitudes of residuals in a power system are determined by many characteristics of the system, and the effects of some of these other characteristics may be substantially greater than the effect of non-transpositions. Thus, power circuit transpositions have only a slight effect on the magnitude of noise frequency induction from residuals.

Furthermore, recent studies apparently indicate that coordinated power circuit transpositions in general have small effect on the average metallic circuit induction from balanced components inside the exposure section. The effect of power circuit transpositions on longitudinal circuit induction from balanced components depends upon the particular conditions present, and they will effect some reduction in the absence of important effects from residual components.

Configuration and Spacing. The configuration of a power circuit has a large effect on the intensity of induction from balanced components, but has only a very small influence on induction from residuals. Induction from balanced components increases nearly in direct proportion to the conductor spacing, but induction from residuals, particularly from residual current, is only slightly affected by conductor spacing, since the return circuit is in the ground. The effect of various configurations and spacings is thus important only from the standpoint of induction from balanced components, and from the practical standpoint may have little effect when the induction is predominantly residual in character.

Distribution Circuits. The results of the wave shape survey recently conducted indicate that the average voltage wave shape of all types of distribution circuits is approximately the same, with an average voltage telephone interference factor of approximately 20. The non-triple harmonic phase currents and current telephone interference factors on feeders supplying industrial loads are somewhat larger than on feeders supplying residential loads, due to the harmonics generated in the rotating machinery on industrial feeders. The triple harmonic phase and residual currents (particularly the third harmonic) are larger on 3-phase, 4-wire residential circuits than on other types, due to the effect of single-phase-load transformers connected phase-to-neutral.

Single-Phase Taps. It is often necessary for a power system to use single-phase branches when extending service into territories of small load density. The effect of such single-phase circuits as regards induction depends upon the type of load, type of circuit, the characteristics of the power system, whether direct at generator voltage or transformed, and the magnitude of the exposure.

Single-phase taps with ground return are not considered good practice since the flow of return current in the earth may cause considerable inductive effect in any paralleling communication circuit. A single-phase metallic circuit tapped from a 3-phase circuit will cause an unbalance in the charging current to ground and in the load current in the 3-phase circuit. The charging current to ground usually contains harmonic frequencies and this may cause noise due to residual electromagnetic induction. The unbalanced load current in the 3-phase portion will usually not cause trouble since its magnitude is small and it consists of balanced components at the fundamental frequency.

When several single-phase taps are taken from a 3-phase circuit, they should be arranged so that the wire miles connected to each phase in a given area is as near balanced as possible, as well as having the load current in each phase reasonably well balanced. The balancing of the wire miles is of prime importance. The balancing of single-phase taps is also advantageous from the standpoint of voltage regulation and losses in the power circuit as well as from the standpoint of inductive effects.

Series Street Light Circuits. With series street lighting circuits, when a lamp used with an individual transformer burns out and the film cut-out fails to operate, the total current becomes magnetizing current in the out lamp transformer. This causes a very substantial increase in the harmonic content of the voltage wave and thus greatly increases the inductive influence of the entire street lighting circuit. It is desirable from the standpoint of the power company as well as from the standpoint of inductive coordination to provide suitable film cutouts with series transformer installations.

Voltage Regulation of Distribution Cables

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Distribution of alternating current at low voltages requires careful consideration of the various factors influencing voltage regulation. In order to keep the regulation as nearly constant as possible over a range of currents and power factors, certain optimum ratios of circuit resistance to reactance are desirable. Studies presented in this article have been made to facilitate the selection of these ratios. Cost data for various circuit arrangements also are given.

DESIGN of a distribution system for alternating current at low voltages does not depend primarily upon the selection of a conductor size thermally sufficient to carry the load, but depends upon the voltage regulation limits which will be satisfactory for lighting, especially when combined light and power loads are carried on the same circuit. Voltage regulation by definition is the ratio of the difference between the impressed voltage and received voltage to the received voltage, expressed as a percentage, and thus for any circuit carrying alternating current it becomes a function of the magnitude of the current, the power factor, and the circuit impedance. Only the first of these factors approximates a simple linear relation to the voltage regulation.

Circuits which contain the larger values of inductance give poorer voltage regulation with low power factor currents because the inductive voltage drop is more nearly in phase with the line voltage. Similarly, circuits with the larger values of resistance give poorer voltage regulation with high power factor currents. If consideration were given only to regulation at unity power factor, then the physical size of the conductor would furnish an index of the inverse proportionality between voltage regulation per unit length and increasing sizes of conductors. However, if load currents of lower and lower lagging power factors are applied it soon becomes apparent that the inductance component of the impedance becomes the major parameter affecting the voltage regulation.

If a choice of circuits constants be made such that certain ratios of resistance to reactance obtain, it is possible to produce quite different trend curves of voltage regulation. Considering a constant value of voltage regulation for circuits having equal values of impedance, the ratio of current at any power factor to the minimum current giving that value of regula-

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Essentially full text of "Voltage Regulations of Cables Used for Low-Voltage A-C Distribution" (No. 32-119) presented at the A.I.E.E. Middle Eastern District Meeting, Baltimore, Md., October 10–13, 1932.

tion may be calculated for various ratios of resistance to reactance. The ratio of these currents is given by the following formula:

$$i/i_{min} = \frac{\sqrt{(r\cos\theta + x\sin\theta)^2 + z^2[(1+\gamma)^2 - 1]} - (r\cos\theta + x\sin\theta)}{z\gamma}$$

where

i = load current at any power factor
i_{min} = minimum current giving same regulation. (It is at a power factor such that $\theta = \tan^{-1} x/r$)
r = circuit resistance
x = circuit reactance
z = circuit impedance
γ = voltage regulation = $(E_i - E_r) \div E_r$

Such a set of data is shown graphically in Fig. 1. It will be noted that if the ratio of resistance to reactance is less than unity the per cent current which may be carried to give equal values of regulation decreases very rapidly with decreasing power factor. On the other hand, if a relatively large ratio of resistance to reactance is selected, the current becomes an increasing function for equal regulation at the lower power factors. Thus, if a choice could readily be made, it would seem desirable to choose a ratio of resistance to reactance of something between 1.5 and 2.0 for a circuit which would be subject to variable lagging power factor loadings, as ratios near these values tend to give more nearly uniform voltage regulation over a range of power factors from 50 to 100 per cent. In applying such a selection of ratios of resistance to reactance to the design of a-c circuits, one is immediately faced with the problem that while the resistance per unit length of the circuit is variable depending only on the physical size of the conductor, the reactance per unit length of the given circuit is almost independent of the physical size of the conductors and for a single circuit with cables can only be changed by changes in cable construction. Thus in order to obtain a certain optimum ratio of resistance to reactance for a circuit, there are in general, 3 courses of attack: first, for a given physical size, the reactance component may be changed by changing the cable construction (single conductor or multi-conductor cables with sector type or concentric type construction), second, by changes in the physical size of the conductor, and third, by paralleling 2 or more circuits.

CONCENTRIC CABLES

Concentric cable construction has long been used for feeders on low-tension d-c distribution because of the space factor consideration. For 3-phase a-c distribution this type of construction applied to 3 conductors instead of 2 gives the minimum reactance per unit length which it is possible to obtain with a single circuit for a fixed value of insulation thickness. In addition, this construction gives a very flat regulation curve for physical conductor sizes which would be commonly used for distribution purposes, that is, sizes from 4/0 to 500,000 cir mils. The construction, however, does not lend itself readily to permit splicing operations to be made while the cable is alive, therefore, while this type of construction might prove very satisfactory for radial feeders to individual motors, it would not be practical for use in making up a secondary network grid.

SECTOR CABLE, 3-CONDUCTOR

Three-conductor sector cable provides, by constructional features, the next higher reactance per unit length for single circuits. Its use again is subject to the same limitations as for the concentric type construction in that splicing operations cannot be made readily while the cable is alive.

SINGLE CONDUCTOR CABLE

Single conductor cables have the highest reactance per unit of length of all the types of cable construction in commercial use due to the increased spacings which result between conductors. While the disadvantage of the relatively high reactance component has long been realized this type has found almost universal favor in the construction of alternating current mains because of practical splicing considerations. If it were desired to obtain a relatively flat regulation curve with a single circuit of single conductor cable, it would be necessary to use rather small physical sizes in order that the optimum ratio of resistance to reactance be maintained.

MULTI-CIRCUITS OF SINGLE CONDUCTOR CABLES

Since information on single conductor cable indicates that good regulation would obtain over a considerable range of power factor only with the use of small physical sizes, it would of course become obvious that several circuits of the smaller size cables could be paralleled thereby maintaining the same ratio of resistance to reactance while obtaining the actual values of resistance to provide sufficient current carrying capacity. However, when 2 or more circuits are placed in close proximity the reactance of the parallel circuit is made up not only of the self-inductance of the circuit but also of the mutual inductance between the circuits. By altering the physical arrangements of conductors in a twin circuit for 3-phase distribution made up of 6 conductors, it is possible to have the mutual inductance become either additive or subtractive from the self-inductance of each circuit. This results in the over-all reactance of the circuit being either somewhat greater

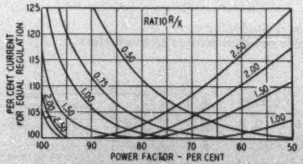


Fig. 1. Ratio of load current at various power factors to minimum current giving equal values of voltage regulation, with equal circuit impedances, for various ratios of R to X

or somewhat less than one-half the reactance of a single circuit.

The voltage regulation which obtains with twin circuits depends in part also on the mutual phase relations which exist between the several conductors. These various arrangements are shown in Fig. 2. The arrangement *a* results in the minimum voltage regulation and arrangement *e* in the maximum voltage regulation. A comparison of the voltage regulation which obtains with these 2 limiting arrangements of twin circuits of 4/0 single conductor cables and with a single circuit of 500,000-cir-mil single-conductor cable carrying the same load current, 400 amp, is shown in Fig. 3.

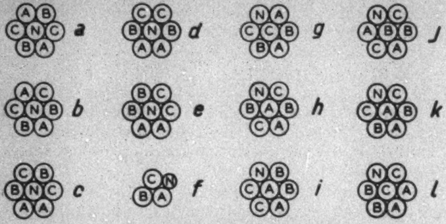


Fig. 2. Phase conductor positions for various twin circuit arrangements

SIXTY-CYCLE REACTANCE OF CABLE

Formulas for calculating the reactance of the various conductor arrangements are as follows:

THREE SINGLE CONDUCTORS

The reactance per conductor of 3 single conductors carrying balanced 3-phase currents, for equal spacing, is

$$x = 0.0529 \log_{10} \frac{s}{a} + 0.00574 \text{ ohms per 1,000 ft}$$

where

a = radius of conductor
s = distance between centers of conductors

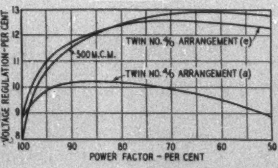


Fig. 3. Voltage regulation per 1,000 circuit ft with load current of 400 amp

For 2 arrangements of twin circuits of 4/0 cable and for a single circuit of 500,000-cir-mil cable

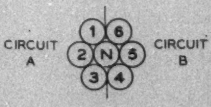


Fig. 4. Arrangement of twin circuits consisting of single conductor cables, indicating subscript designations

TRIPLE CONCENTRIC CABLE

The reactance per conductor of triple concentric cable for this study was taken as the average of values obtained from the following:

1. Between inner and center conductors and between inner and outer conductors.

$$x = 0.0529 \log_{10} \frac{b_1}{a_2} + 0.0115 \left(\frac{1}{2} + \frac{1}{3}\frac{a_2^2}{b_1^2} - \frac{1}{12}\frac{a_2^4}{b_1^4} + \ldots\right)$$

ohms per 1,000 ft

where

a_2 = outer radius of inner conductor
b_1 = inner radius of outer conductor

2. Between center and outer conductors:

$$\overline{x = 0.01151}\left[4.606 \log_{10} \frac{b_1}{a_2} + \frac{4.606 a_1^4}{(a_2^2 - a_1^2)^2} \log_{10} \frac{a_2}{a_1} + \frac{4.606 b_2^4}{(a_2^2 - a_1^2)^2} \log_{10} \frac{b_2}{b_1} - \frac{a_1^2 + b_2^2}{a_2^2 - a_1^2}\right] \text{ ohms per 1,000 ft.}$$

where

a_1 = inner radius in cm of inner conductor
a_2 = outer radius in cm of inner conductor
b_1 = inner radius in cm of outer conductor
b_2 = outer radius in cm of outer conductor

TWIN CIRCUITS

Reactance of twin circuits—while numerous arrangements of twin circuits are possible as has been indicated in Fig. 2, formulas are only included for the first 5 cases as these cover all the possible arrangements when the neutral conductor is maintained in the central position of the group. Referring to Fig. 4 it will be noted that the conductors have been given numbers in order to simplify the subscript designation and each of the following equations gives the average 60-cycle reactance for the individual conductors. The following symbols are used:

a = radius of conductor
S_{12} = distance between centers of conductors 1 and 2
S_{13} = distance between centers of conductors 1 and 3, etc.

1. Reactance for arrangement shown in Fig. 2*a*

$$X = 0.01149 \times \left[0.5 + 4.606 \log_{10} \frac{(S_{12}S_{13}S_{23})^{1/3}}{a} \frac{(S_{51}S_{61}S_{42}S_{62}S_{43}S_{53})^{1/6}}{(S_{41}S_{52}S_{63})^{1/3}}\right]$$

ohms per 1,000 ft

Table I—Comparison of Calculated and Measured Constants

Arrangement	Impedance (10^{-3} ohms/ft)				Measured % Unbalanced in Current Between Conductors
	Calculated		Measured		
	R	*X*	*R*	*X*	
a	25.70	15.79	25.76	16.96	2.0
b	25.70	17.60	28.10	17.76	14.8
c	25.70	21.50	27.16	23.04	13.0
d	25.70	23.90	29.16	24.20	1.6
e	25.70	27.74	30.40	28.18	14.8
f*	22.80	31.20	25.22	32.16	
g			28.60	17.74	10.1
h			27.12	17.48	6.0
i			29.80	24.80	5.6
j			28.96	18.00	13.8
k			27.22	18.28	5.8
l			29.72	24.42	12.7

* Arrangement f is single circuit of 3 single conductor 500,000-cir-mil cables and a 4/0 neutral.
All the other arrangements are twin circuits of 6 single conductor 4/0 cables and a 4/0 neutral.

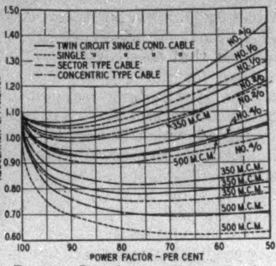


Fig. 5. Regulation efficiency of various types of cable

Regulation efficiency expressed in amperes per 1,000 cir mils for one per cent regulation per 100 ft

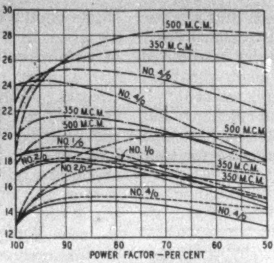


Fig. 6. Cost of current carrying capacity of various types of cable

Cost expressed in cents per ampere per 100 circuit ft for one per cent regulation

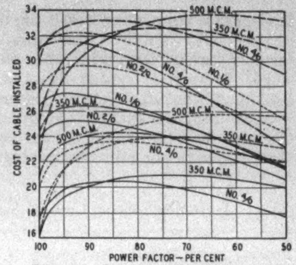


Fig. 7. Cost of current carrying capacity of installed cable of various types based on low market prices for metal

Cost expressed in cents per ampere per 100 circuit ft for one per cent regulation

Table II—Relative Costs of Cable in Per Cent Per Unit Circuit Length

Cable Size	*Single Cond. Cable (3 Cables)	†Sector Cable	†Concentric Cable
1/0	100	148	181
2/0	116	173	213
4/0	140	243	262
350,000 cir mils	221	365	360
500,000 cir mils	300	470	455

* Low tension cable, rubber insulated, lead sheathed.
† Low tension cable, 3-conductor, paper insulated, lead sheathed.

2. Reactance for arrangement shown in Fig. 2*b*

$$X = 0.01149 \times \left[0.5 + 4.606 \log_{10} \frac{(S_{12}S_{23}S_{13})^{1/3}}{a} \frac{(S_{61}S_{52}S_{43})^{1/6}}{(S_{62}S_{53}S_{41})^{1/6}}\right]$$
ohms per 1,000 ft

3. Reactance of arrangement shown in Fig. 2*c*

$$X = 0.01149 \times \left[0.5 + 4.606 \log_{10} \frac{(S_{12}S_{13}S_{23})^{1/3}}{a} \frac{(S_{41}S_{53}S_{52}S_{61}S_{42}S_{63})^{1/6}}{(S_{62}S_{51}S_{43})^{1/3}}\right]$$
ohms per 1,000 ft

4. Reactance of arrangement shown in Fig. 2*d*

$$X = 0.01149 \times \left[0.5 + 4.606 \log_{10} \frac{(S_{12}S_{13}S_{23})^{1/3}}{a} \frac{(S_{41}S_{51}S_{42})^{1/3}}{(S_{61}S_{52}S_{43})^{1/3}}\right]$$
ohms per 1,000 ft

5. Reactance of arrangement shown in Fig. 2*e*

$$X = 0.01149 \left[0.5 + 4.606 \log_{10} \frac{(S_{12}S_{13}S_{14}S_{15})^{1/2}}{aS_{16}}\right]$$
ohms per 1,000 ft

TEST RESULTS WITH SINGLE CIRCUITS AND TWIN CIRCUITS OF SINGLE CONDUCTOR CABLE

In order to check the differences which a theoretical study indicated to exist between single circuits and twin circuits of single conductor cable a test set-up was made with 500 circuit ft of 3 single conductor cables of 500,000 cir mils and a 4/0 neutral for the single circuit, and 500 circuit ft of 7 single conductor cables of 4/0 size for the twin circuit arrangements. Test results indicated agreement with the calculated values within the precision of measurements used in the test, and are summarized in Table I. It will be noted that there is an effective increase in the resistance of the conductors in single conductor lead sheathed cable due to sheath losses and these are not entirely negligible in the larger sizes of cable even when the 3 cables are mutually tangent. These sheath losses give an apparent increase in conductor resistance of 5.5 per cent for 500,000-cir-mil single-conductor cables, 2.3 per cent for 350,000-cir-mil single-conductor cables and 0.7 per cent for single conductor cables.

SPACED CONDUCTORS

From the foregoing, it follows that busses and separated conductors (such as are generally used in temporary construction service) have inherently high reactance. The use of these configurations should be avoided where good voltage regulation is required unless the circuit length is short.

REGULATION EFFICIENCY

The regulation efficiency, that is, the amperes per 1,000 cir mils which may be carried in a given cable to give one per cent voltage regulation per 100 circuit ft, on a 3-phase 4-wire 120/208 volt circuit for the various types of construction and sizes of cable is shown in Fig. 5. It will be noted for any given type of cable construction that the regulation efficiency improves with the smaller wire sizes of cable, and that by types of cable construction, the concentric type has the greatest efficiency, the sector type the next better efficiency and single conductor the poorest efficiency, with the twin circuits of single conductor cable lying between the values for single conductor cable and sector type of cable.

While the concentric type of cable construction has the highest regulation efficiency, it is also the most expensive. Based upon manufacturers' figures (market value of copper and lead being 6 cents and 3 cents, respectively) Table II indicates the relative costs for the various sizes and types of cables where 1/0 single conductor rubber insulated lead sheathed cable has been taken as the base at 100 per cent.

Combining the data of the regulation efficiency and the cost of cable, trend curves are obtained which show the cost per unit of carrying capacity for unit regulation with various power factors. These curves are shown in Fig. 6. These data indicate that there is a spread of some 85 per cent in cost for the various cable sizes usually found in practice to give the same regulation per unit length of circuit.

Table III—Splicing Costs of Single Circuits

Cable Size	Relative Cost of Splicing in Per Cent
1/0	100
2/0	111
4/0	122
350,000 cir mils	132
500,000 cir mils	140

COST OF CABLES INSTALLED

The previous cost data includes only the cost of cable, but the true economic study of relative cost should be based on cables installed and spliced, particularly where the installation cost may be somewhat different for the different types of cable construction and arrangement. Based upon field studies it is indicated that the pulling-in charges for twin circuits, 6 single conductor cables and neutral in the same duct is about 10 per cent greater than the charges for 4 single conductor cables or for a multiconductor cable.

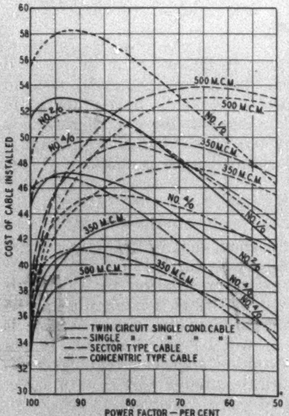


Fig. 8. Cost of current carrying capacity of installed cable of various types based on high market prices for metal

Cost expressed in cents per ampere per 100 circuit ft for one per cent regulation

The relative costs of splicing single circuits of single conductor cable and multi-conductor cable are given in Table III. Field studies on the splicing of twin circuits indicated that this cost was about 50 per cent greater than for the splicing of single circuits. With the cost of installing and splicing cable added to the cost of the cable a new set of trend curves (Fig. 7) is obtained which shows the total cost per unit circuit length to give equal regulation at various power factors.

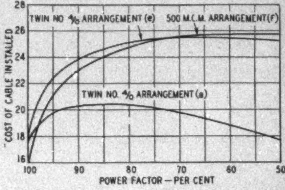
It is also of interest to know to what extent the variations in the metal market may be reflected in the cost of regulation of the various types and sizes of cable. A set of curves has been prepared in Fig. 8 showing this cost based on copper and lead prices of 18 cents and $6^1/_2$ cents per lb, respectively.

CONCLUSIONS

The economic comparisons as indicated in Figs. 7 and 8 show that with low market prices for metal twin circuits with 4/0 single conductor cables provide the most economical distribution unit. At relatively high market prices for metal both 350,000-cir-mil and 500,000-cir-mil concentric type cable show a slightly lower cost than twin circuit of 4/0 cables. While these concentric type cables might prove adaptable to construction which is not required to be worked alive it appears that for low voltage main cable, the twin circuits of 4/0 cable hold an economic advantage whether the metal market be high or low.

Fig. 9. Effect of phase arrangements on the cost of current carrying capacity

Cost expressed in cents per ampere per 100 circuit ft for one per cent regulation



Field experience has indicated that it is practical to keep relative phase arrangements during pulling in and splicing of the cable and thereby secure the maximum economic use of the twin circuit main. The comparative cost of installed cable between the most favorable and least favorable arrangement of twin circuits of 4/0 cable and a single circuit of 500,000-cir-mil cable is shown in Fig. 9. Actual investment per circuit ft is substantially the same for either of these 2 types of construction. It will be noted that at low power factor even the most unfavorable arrangement of twin circuits is preferable to a single circuit.

In all the theoretical material included in this paper the reactance values used have been calculated on assuming the cables to lie mutually tangent. This condition has been found to hold to a fair degree of approximation in the case of twin circuits installed in a common duct but single circuits usually show an appreciable increase in reactance over the calculated values for close spacing due to their spreading out in the duct.

Traveling Wave Voltages in Cables

Cables connected directly to overhead transmission lines may require protection against lightning. The factors which determine whether or not protective equipment is necessary are discussed in this article and new and simplified formulas for determining the maximum voltage are presented. The effect of cable length and surge impedance and of line surge impedance are illustrated in detail and tentative data on impulse strength of cable insulation are included.

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IN the earlier days of the electrical industry, comparatively little attention was paid to the protection of cables against lightning surges. Where cable lines were not connected to overhead lines, or where they were connected to such lines through transformers, special devices for the protection of cables were unnecessary, since the lightning surges impressed on such cables were seldom if ever of great severity. Furthermore, the high impulse ratio of cable insulation, together with the inherent tendency of cables, especially long ones, to reduce the magnitude of an entering wave to a relatively low value, has tended to make cables self-protecting. These factors still make protection unnecessary in many cases.

During the last decade, however, the maximum voltage at which cables have been successfully operated in commercial service has steadily increased; and there is reason to believe that this voltage will increase yet further in the future. This fact has resulted in an increasing use of short cable sections on high tension transmission lines; both at the end of a line, where overhead transmission is often impractical, and at points along the length of a line. Such links, being short, are not necessarily self-protecting. Again, the great advances made during this period in the art of cable manufacture have resulted in a considerable increase in the life of cables, and in their dielectric strength at operating frequencies; this improvement has been greater than the corresponding improvement in impulse strength. Finally, the cost of a high voltage cable section is by no means negligible, and its importance from the operating standpoint is usually very great.

On the other hand, the cost of high voltage protective equipment is often an appreciable item in the total cost of the cable section or cable line. It becomes increasingly important, therefore, to determine with some precision just when such equipment is required, and when it can safely be dispensed with.

The movement for the coordination of insulation which is at present on foot makes it particularly desirable to insure that a cable shall not prove to be a weak link in a system. It is because of this movement that formulas have been developed in terms of exponential wave shapes which approximate closely to the actual shapes of the coordinating waves. These formulas, incidentally, afford a method of calculation which is very much simpler than the "step-by-step" method (see reference 1) usually used for such work. Moreover, calculations can be made by these formulas in a much shorter time.

The factors which determine whether a cable needs lightning protection or not are as follows:

1. The magnitude of the incoming wave. This is usually limited by the impulse flashover of the line insulation or cable terminal, or possibly by a coordinating gap.
2. The effect of the cable and line surge impedances on the traveling wave.
3. The effect of the impedance at the far end of the cable.
4. The length of the cable, and its dielectric constant.
5. The impulse strength of the cable.

These last 4 factors are discussed in more detail in the following paragraphs.

Effect of the Cable on the Traveling Wave

When a traveling wave on an overhead line reaches a cable, a wave of reduced voltage passes into the cable. This reduction is due to the fact that the surge impedance of a cable is less than that of an overhead line. In a traveling wave the electrostatic energy is equal to the electromagnetic energy and the constants of a cable are such that the voltage of a traveling wave has a lower ratio to the current than in the case of a wave on an overhead line.

After the wave enters the cable there are voltage and current reflections back and forth from each terminal. If the length of the original wave is great enough there will be several superimposed waves at each point in the cable. The sum of these several waves will be dependent upon the shape of the original wave as well as the reflection from each end of the cable.

The reflection at the cable terminal depends upon the surge impedances of the cable and of the connected line or apparatus. In this article, calculated values of voltage are given for a range of cable surge

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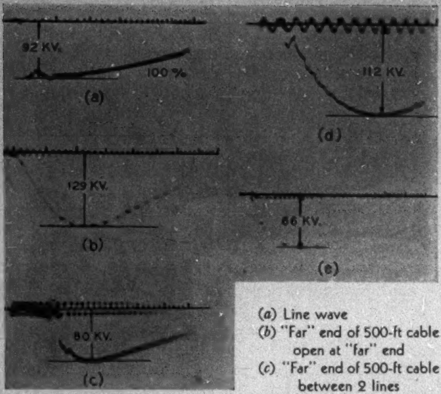
Essentially full text of "Traveling-Wave Voltages in Cables" (No. 32-118) presented at the A.I.E.E. Middle Eastern District meeting, Baltimore, Md., Oct. 10-13, 1932.



(*a*) Line wave
(*b*) "Far" end of 500-ft cable open at "far" end
(*c*) "Far" end of 500-ft cable between 2 lines
(*d*) "Far" end of 1,000-ft cable open at "far" end
(*e*) "Far" end of 1,000-ft cable between 2 lines

Fig. 1. Oscillograms of traveling wave voltages measured at "far" end of cable

impedance from 20 to 150 ohms and line impedances of 300 and 500 ohms. The calculations include the case of similar lines connected to each end of the cable, and the case of a line connected to one end of the cable only and a free terminal at the other, which is the case giving the highest voltage. The traveling wave is assumed to enter at the "near" end of the cable and the voltage at the "far" end calculated, since in general the maximum voltage will be found at that end. Reduction of the wave by cable losses is neglected, as tests have shown the losses to be small in 500-ft and 1,000-ft lengths of cable.

TYPICAL WAVES USED IN CALCULATIONS

Three different waves have been used in various coordination studies. They are the $^1/_2$ x 5, the 1 x 10 and the $1^1/_2$ x 40, in which the first figure is the time in microseconds to reach crest, and the second figure the time to reach half value on the tail of the wave. However, since both tests and calculation show that short wave fronts do not greatly affect the ultimate voltage resulting in the cable, and since turn-to-turn stresses in apparatus due to steep wave fronts are not being considered here, the mathematical treatment of the problem in this paper has been simplified by using the 0 x 5, 0 x 10 and 0 x 40 waves. The waves have, respectively, the following formulas: $E\epsilon^{-0.138t}$, $E\epsilon^{-0.0692t}$, and $E\epsilon^{-0.0173t}$; they will give slightly higher values for ultimate cable voltage than would be obtained from the first mentioned waves.

DERIVATION OF FORMULAS

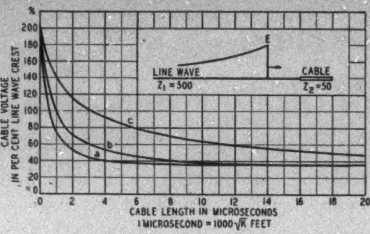


Fig. 2. Maximum voltage at "far" end of cable

Resulting from (*a*) 0 x 5, (*b*) 0 x 10, and (*c*) 0 x 40 line waves. Cable open at "far" end

With these waves entering the cable the voltage at the cable terminals will rise to its maximum value and then decrease in a series of steps by successive reflections, each step having a vertical front. The principal interest in this article is to determine the maximum value to which the voltage rises in the cable rather than its rate of rise. Under these conditions, simple formulas for the maximum voltage at either cable terminal for the *n*th step, and also the step at which the voltage will be a maximum, are determined as follows:

Assume a wave of vertical front and sloping tail represented by $E\epsilon^{-BT}$ and traveling on a line of surge impedance Z_1 into a cable of surge impedance Z_2 with a line of surge impedance Z_3 at the "far end." The front of the first wave entering the cable is:

$$\frac{2Z_2}{Z_1 + Z_2} E$$

This front is reflected at the "far end" of the cable, producing a total instantaneous voltage AE where

$$A = \frac{2Z_2}{Z_1 + Z_2}\left[1 + \frac{Z_3 - Z_2}{Z_3 + Z_2}\right]$$

The reflected wave travels back to the "near end" of the cable where it is reflected again, thus producing a second entering wave which is M times the first wave and which results in an additional voltage at the far end of M times that produced by the first wave. Similarly there is a third entering wave, M times the second wave or M^2 times the first wave, etc. M is the product of the 2 reflection factors,

$$M = \frac{Z_1 - Z_2}{Z_1 + Z_2} \times \frac{Z_3 - Z_2}{Z_3 + Z_2}$$

and is always less than 1. Therefore, each entering wave is less than the preceding entering wave, part of the wave having been lost by transmission back into the line. Each of these waves has a vertical front and falling tail. Thus the voltage at the "far end" of the cable rises and then falls in a series of steps. At each step the voltage rises vertically and then falls until the next step. Therefore, the maximum voltage occurs at the beginning of one of these steps. If T is the time required for a wave to travel twice the length of the cable, then at the beginning of the *n*th step the voltages of the preceding waves at the "far end" of the cable have been reduced by the factors ϵ^{-BT} ϵ^{-2Bt}, etc.

Therefore the total voltage at the *n*th step is:

$$E_{23}(n) = AE[M^{n-1} + M^{n-2}\epsilon^{-BT} + \ldots M^{n-n}\epsilon^{-(n-1)BT}]$$

This series is equal to the equivalent fractional expression:

$$E_{23}(n) = AE\,\frac{M^n - \epsilon^{-nBT}}{M - \epsilon^{-BT}}$$

The formula value for n to give maximum value of E_{23} is:

$$n = \frac{\log \dfrac{-BT}{\log M}}{BT + \log M}$$

If this value of n is not a whole number, then the 2 nearest whole numbers should be tried to determine which gives the maximum value. Usually, but not always, the nearest whole number gives the maximum value. The time at which the maximum value occurs is found by multiplying T by the number of steps. In the above formula $\log M$ is negative since M is always less than one.

The formula for E_{12} at the near cable junction is derived in a similar way.
Let

$$F = \frac{Z_3 - Z_2}{Z_3 + Z_2} \text{ reflection factor at far terminal}$$

$$A^1 = \frac{2Z_2}{Z_1 + Z_2}$$

Then the initial voltage is A^1E.

The voltage at the second step is:

$$A^1E\epsilon^{-BT} + A^1E(M + F)$$

The voltage at the nth step is:

$$E_{12}(n) = A^1E\left[\frac{M^{n-1}(M + F) - \epsilon^{-nBT} - F\epsilon^{-(n-1)BT}}{M - \epsilon^{-BT}}\right]$$

The value of n for maximum E_{12} is:

$$n = \frac{\log \dfrac{-BTM(1 + F\epsilon^{BT})}{(M + F)\log M}}{BT + \log M}$$

Fig. 6 shows how the value of n varies with the cable length for the case of a cable at the end of a line, the far end of the cable being open.

COMPARISON WITH FIELD TESTS

Results obtained by the above method check closely the field measurements obtained by Messrs. McEachron, Hemstreet, and Seelye, in the Michigan tests on cables.[2] Oscillographic measurements from the Michigan tests are shown in Fig. 1. In Table I is given the relation between the calculated and measured values for approximately the same conditions. The line surge impedance was 500 ohms, the cable impedance 50 ohms and there was a 2 x 50 wave arriving over the line.

EFFECT OF WAVE SHAPE

As pointed out, the voltage resulting in the cable is dependent upon the shape of the incident wave. This is shown in Fig. 2 for voltages at the "far" end resulting from the 3 waves. The line impedance was taken as 500 ohms and the cable impedance 50 ohms. The "near" terminal of the cable is connected to the overhead line and the "far" terminal is free, i. e., having no electrical connections. To make the curves general, the cable length is plotted in microseconds since the wave propagation velocity varies in different cables. The length of the cable in microseconds is approximately equal to the cable length in thousands of ft multiplied by $\sqrt{K}$, the square root of dielectric constant of the cable insulation. This relation is due to the fact that the propagation velocity of electric waves is inversely proportional to the square root of the permittivity or dielectric constant of the insulating medium.

Table I—Comparison of Measured and Calculated Voltages

	Measured	Calculated
Line to 500 ft cable open at far end	142%	150%
Line to 1,000 ft cable open at far end	120%	124%
Line to 500 ft cable to line	87%	82%
Line to 1,000 ft cable to line	72%	74%

It may be noted in Fig. 2 that cable voltage is greater for the waves which decrease more slowly with time. This difference is more pronounced for the shorter lengths of cables. For example, in a 2-μsec cable which might be approximately 1,100 ft in length, a 0 x 40 wave rises to 117 per cent, a 0 x 10 wave rises to 72 per cent and a 0 x 5 wave rises to 54 per cent. These values are referred to the crest of the incident wave or original wave arriving over the line, which is 100 per cent.

Although the curves cover a range of lengths up to 20-μsec only, it should be noted further that where the cable is sufficiently long the voltage at the "far" end is equal to the first entering wave plus its reflection, the effect of further reflections being negligible.

EFFECT OF LINE SURGE IMPEDANCE

To show how surge impedance of the line affects the cable voltage, curves are given for 2 values of line impedance, 300 and 500 ohms, with the 0 x 40 wave and 50-ohm cable impedance as shown in Fig. 3. These curves show that a higher surge impedance of the line results in a lower voltage in the cable. The effect is greater with longer cables.

EFFECT OF CABLE SURGE IMPEDANCE

The manner in which cable surge impedance affects the resulting voltage is shown in Fig. 4. In this case the cable impedance was varied from 20 to 150 ohms while the other factors were kept constant. In practice the cable surge impedance varies over a relatively greater range than the line impedance. These curves show a wide difference of cable voltage for the 8 values of cable surge impedance examined. For example, with an 8-μsec cable, the voltage varies from 40 per cent to about 120 per cent for impedances of 20 and 150 ohms, respectively.

EFFECT OF IMPEDANCE AT "FAR" END OF CABLE

Where a line is connected at the "far" end of the cable, as shown in Fig. 5, the reflected voltage, and therefore the resultant voltage, is less than that for an open-end cable where full reflection occurs. This

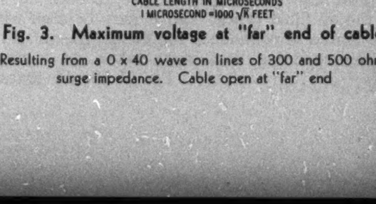


Fig. 3. Maximum voltage at "far" end of cable

Resulting from a 0 x 40 wave on lines of 300 and 500 ohms surge impedance. Cable open at "far" end may be seen by comparing the curves in Fig. 5 with the corresponding curves in Fig. 4. Take the case of a 20-μsec cable of 30 ohms surge impedance, the voltage is about 33 per cent in Fig. 4 and about 28 per cent in Fig. 5. This difference is small. But if the cable length is decreased to 2-μsec, the cable voltage is about 97 per cent in Fig. 4 and nearly 63 per cent in Fig. 5. These curves show that the impedance connected at the "far" end of the cable is more important in the case of shorter cables. As the cable length approaches zero, the cable voltage approaches 100 per cent in Fig. 5 where the "far" end of the cable is connected to a line, and 200 per cent in Fig. 4 where the "far" end of the cable is an open circuit. When apparatus is connected to the "far" end of the cable and has a high impedance compared with the cable, the condition is approximately that of open circuit at the "far" end. This assumption always gives a value of voltage in the cable which is slightly higher than the value which actually will occur where the cable terminates in station apparatus. The matter of terminal impedances has been covered in more detail by Bewley. (See reference 12.)

IMPULSE STRENGTHS

Data on the impulse strength of cables are very meager at the present time, although a test program is under way which should go far in extending the knowledge now available. The curve given in Fig. 7 is based on somewhat limited data, taken with the 3 coordinating waves previously referred to. The curve actually represents an average value of all the data obtained, since it appeared from the tests that the difference in wave shape did not greatly affect the value of breakdown. The curve is suggested tentatively for use in connection with the present formulas as a guide to a decision as to whether protection is or is not required. It should, of course, be used with a suitable factor of safety. The data was taken on impregnated paper cable, of both the solid and the oil filled types; and it may be used with a good degree of confidence for these types of cables. No corresponding data were taken on varnished cambric or rubber cable. Fig. 7 should therefore be used with great caution when considering these types of cable.

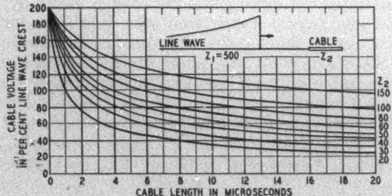


Fig. 4. Maximum voltage at "far" end of cables of various surge impedances

Resulting from a 0 x 40 wave on a line of 500 ohms surge impedance. Cable open at "far" end

Tables giving line flashover values for various numbers of standard $5^3/_4$ by 10 in. disk insulators have been published in a number of places by F. W. Peek, Jr.[3,4] The impulse strength of wood pole lines may be estimated from the length of wood in circuit to ground.[5,6]

CABLE SURGE IMPEDANCE

The surge impedance of the cable can be determined from the formula:

$$Z\text{ (cable)} = \frac{G}{0.0169\, n \sqrt{K}}$$

where

K = dielectric constant of cable insulation
n = number of conductors
G = geometric factor

Curves of G have been published in several places by Simmons.[6,10] Working values of the cable dielectric constant K for various types of insulation are as follows: 3.5 for paper, solid; 3.4 for paper, oil filled; 4.2 for varnished cambric; and 4.4 for rubber.

Dielectric losses in the cable were neglected when preparing the curves. Results from the Michigan tests indicate that for short cables this loss is not enough to affect the resulting voltages greatly. However, for long cables it is possible that attenuation of the voltage wave due to dielectric losses will result in lowering maximum voltage. Further test data are needed to determine how much attenuation alters the problem.

LIMITING HIGH VOLTAGE IMPULSES

Taking the crest voltage of the assumed incident waves as limited by the lightning flashover of the connected line, these curves and formulas may be used to determine the maximum voltage to which a cable and connected apparatus will be subjected. This value can be compared with the insulation strength of the cable, pothead, and connected apparatus to determine the protective requirements.

Where a cable of comparatively low voltage rating and correspondingly low impulse strength is connected to a wood pole line having high insulation level, the application of lightning arresters at the junction of cable and line becomes especially important, since without an arrester the first transmitted wave in the cable may exceed the cable strength. Assuming that the wave entering the cable is thus limited by an arrester at the line end of the cable, it may still be necessary to use an arrester at the "far" end of the cable to prevent further rise of voltage by reflection, particularly if connected apparatus at the "far" end would not withstand reflection (approaching double value) of the voltage wave passed by the arrester at the junction of cable and line.

For shorter lengths of cables where several reflections occur in the cable before reaching a maximum value, the crest value of voltage will be approximately the same at both ends of the cable. Under such conditions the application of a single arrester may be sufficient protection. Where there is apparatus at the "far" end of the cable, location of the arrester at that end will conform to the general recommendation that the arrester be located within 50 circuit ft of the apparatus for circuits below 69 kv and within 100 circuit ft for circuits above 69 kv.

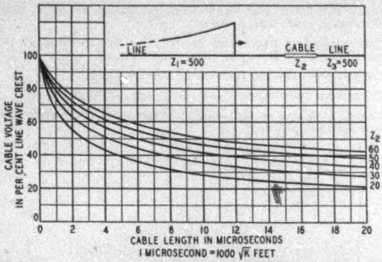


Fig. 5. Maximum voltage at "far" end of cables of various surge impedances

Resulting from a 0 x 40 wave on a line of 500 ohms surge impedance. Cable connected between 2 lines

Practical Example

The application of the curves can be illustrated by calculation of a specific problem. A wooden pole line having an impulse flashover of approximately 1,500 kv is connected to a 2,000-ft section of belted-paper-insulated 3-conductor cable terminating in a substation.

It is assumed that equal waves are arriving on each conductor of 1,500 kv. Under these conditions the surge impedance of each line is taken as 500 ohms. The cable has the following characteristics:

Paper insulation thickness:	
a. Between conductors	0.16 in.
b. Between conductor and sheath	0.12 in.
4/0 conductors (diam)	0.46 in.
Impulse strength	200 kv
Geometric factor (Simmons)	1.2
Dielectric constant	3.5

The surge impedance of the 3 conductors in the cable in parallel is:

$$Z_s = \frac{1.2}{0.0169 \times 3 \times \sqrt{3.5}} = 12.6$$

or 38.0 ohms per conductor.

The cable length in microseconds is:

$$2 \times \sqrt{3.5} = 3.75 \mu\text{sec}$$

Referring to Fig. 4 the maximum unprotected cable voltage as built up by wave reflections is given as 83 per cent of the traveling wave voltage on the line which was 1,500 kv. Therefore, the voltage in the cable would be 1,245 kv. Considering that the impulse strength of the cable is approximately 200 kv, protective equipment for the cable is necessary.

The first transmitted wave at the junction of the cable and line may be obtained from the formula:

$$E_2 = 2E_1 \frac{Z_2}{Z_1 + Z_2} = 212 \text{ kv}$$

Since the cable strength is below this value of the first entering wave, an arrester is warranted at the junction of the cable and line. The first transmitted wave through the cable will approach double value at the "far" end of the cable when the "far" end is open circuited or connected to a transformer or other apparatus of high impedance. An arrester located at the junction of the overhead line and cable, limits the transmitted voltage, but the voltage appearing at the "far" end approaches double arrester voltage. This value should be compared with the strength of connected apparatus and also with cable and pothead strengths to determine the necessity for an arrester at that point.

There may be cases where the cable strength and pothead flashover are somewhat greater than the first transmitted wave, and the point of weakest insulation is in the connected apparatus. In such cases, an arrester should be used to limit the voltage to a safe value for the apparatus, and located at the apparatus end of the cable. In this case additional protection would not seem warranted at the junction of the line and cable except for the case of direct stroke at or near that point.

There are so many ramifications to the problem of cable protection that it becomes very difficult to formulate general rules for their protection which will cover all cases. However, it may be said that where low voltage cables with corresponding low

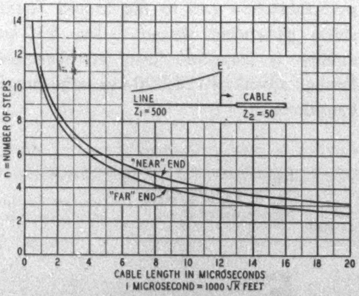
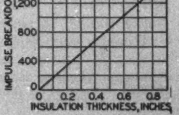


Fig. 6. Number of steps to reach maximum voltage at ends of cable as function of cable length

Cable open at "far" end

Fig. 7. Approximate working values of impulse breakdown of cable insulation

From data on impregnated paper, solid and oil-filled single-conductor, and type *H* 3-conductor cables



impulse strength are connected to highly insulated lines such as a wooden pole structure having ungrounded hardware, safe practice requires the use of adequate arrester protection. Problems where the comparative strengths and lengths have other values may be examined to determine the degree of protection warranted for any particular installation in question.

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Safe Harbor Energy as Used in Baltimore

Energy from the Safe Harbor Hydroelectric Plant is received at Baltimore at a new substation near the Westport steam generating station. At this substation the 230-kv energy is stepped down to 33 kv at which voltage it is transmitted to the 13-kv Westport substation and to the Gould Street steam generating station. The 230-kv energy is stepped down at Westport through a bank of 126,000-kva surge-proof transformers.

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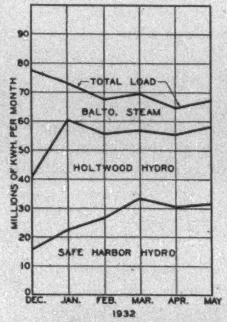

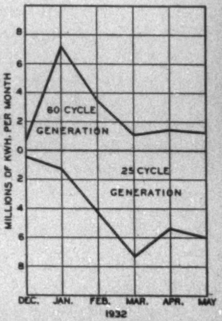

Fig. 1 (left). Total electric power load in Baltimore for the first 6 months after energy was first received from Safe Harbor

Fig. 2 (right). Output of new frequency changer for the same period as Fig. 1; ordinates between the 2 curves give total output in both directions

ENERGY from Safe Harbor was first received at Baltimore in December 1931, and at once assumed an important place in the total energy supply of the city. Previous to 1910 the electric power demands in Baltimore were supplied entirely by steam generated energy. The first hydroelectric energy received in that city came from the Holtwood station on the Susquehanna River, the first generator being placed in service in October 1910.

Energy received from Safe Harbor in the first 6 months of operation is shown in Fig. 1. Energy received from the Holtwood plant during the same period is superimposed upon that received from Safe Harbor, the Baltimore steam plant making up the total load. During the years to come, Safe Harbor energy doubtless will be fully absorbed by the growth of load in Baltimore. Table I gives the installed generating capacities of various steam stations in Baltimore, the installed hydroelectric capacities at both Holtwood and Safe Harbor, and the approximate capacities available at Baltimore.

Territory supplied by the Baltimore system includes an area bounded on the north by the Pennsylvania-Maryland state line, and on the east by the Susquehanna River and Chesapeake Bay; this territory extends west a maximum distance of about 50 miles, and south a maximum of about 70 miles. The system is comprised of both 25- and 60-cycle loads,

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Based upon "Reception and Distribution of Safe Harbor Energy in Baltimore" (32-126) presented at the A.I.E.E. Middle Eastern District meeting, Baltimore, Md., Oct. 10–13, 1932.

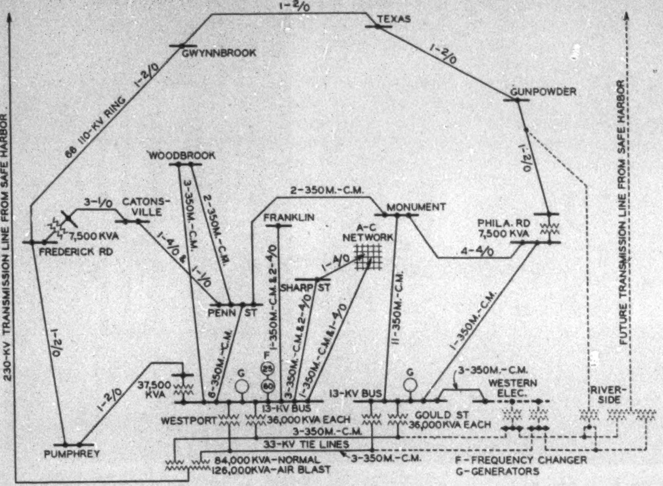
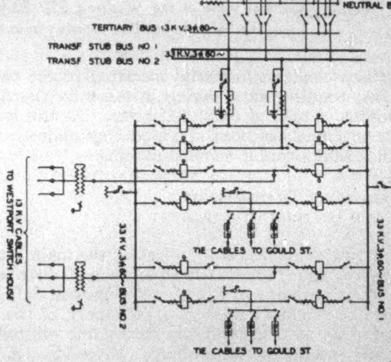

230-KV TRANSMISSION LINE FROM SAFE HARBOR
1-2/0
TEXAS
GWYNNBROOK
68 110-KV RING
GUNPOWDER
FUTURE TRANSMISSION LINE FROM SAFE HARBOR
WOODBROOK
3-1/0
CATONSVILLE
7,500 KVA
FREDERICK RD
3-350M.-C.M.
2-350M.-C.M.
1-4/0 & 1-1/0
2-350M.-C.M.
FRANKLIN
MONUMENT
A-C NETWORK
PHILA. RD 7,500 KVA
4-4/0
SHARP ST
1-4/0
1-350M.-C.M.& 2-4/0
PENN ST
11-350M.-C.M.
1-350M.-C.M.
3-350M.-C.M.& 2-4/0
1-350M.-C.M.& 1-4/0
6-350M.-C.M.
F
G
37,500 KVA
13-KV BUS
3-350M.-C.M.
WESTERN ELEC.
RIVERSIDE
WESTPORT
36,000 KVA EACH
GOULD ST
36,000 KVA EACH
33-KV TIE LINES
PUMPHREY
84,000 KVA-NORMAL
126,000 KVA-AIR BLAST
F-FREQUENCY CHANGER
G-GENERATORS

Fig. 3 (left). Single-line diagram of Baltimore 60-cycle transmission system

Fig. 4 (below). Single-line diagram of Westport 230/33-kv substation


INCOMING 230 K.V. 3φ 60~ LINE FROM SAFE HARBOR
NEUTRAL BUS
SPARE
NEUTRAL BUS
TERTIARY BUS 13 K.V. 3φ 60~
TRANSF STUB BUS NO 1
TRANSF STUB BUS NO 2
33 K.V. 3φ 60~
13 KV CABLES TO WESTPORT SWITCH HOUSE
33 K.V. 3φ 60~ BUS NO 2
33 K.V. 3φ 60~ BUS NO 1
TIE CABLES TO GOULD ST.
TIE CABLES TO GOULD ST

the maximum 25-cycle load recorded being 125,400 kw; the maximum 60-cycle load, 104,800 kw; and the maximum simultaneous load on both frequencies, 188,200 kw. Originally the 25-cycle frequency was chosen as being best adapted for industrial purposes and for application to synchronous converters. However, system growth at this frequency has been deterred in recent years.

In making plans for the reception of Safe Harbor energy in Baltimore, several engineering studies were necessary some of which were made in cooperation with the Pennsylvania Water and Power Company. Some of the more important questions studied were:

1. Voltage of transmission to Baltimore.
2. Stability of the transmission system.
3. Location of terminal stations in Baltimore.
4. Type of transformers to be used to step down the transmission voltage.
5. Step-down voltage and intermediate transmission system.
6. Rearrangement of the Baltimore 13-kv distribution cable system and the voltage regulation of that system.

Results of these studies are indicated by the equipment chosen as described in this article, each decision as a rule being the result of several studies to determine the most economical, reliable, and otherwise satisfactory system and equipment.

CHANGE OF FREQUENCY

Soon after Safe Harbor energy was first received in Baltimore the system frequency which was then $62^1/_2$ cycles was changed to 60 cycles, at which time the older frequency changers were shut down. The sole 25 to 60-cycle frequency changer now operating is at Westport station; it is capable of generating 30,000 kw at either frequency.

Load carried by the frequency changer for the first 6 months of operation is shown in Fig. 2; as may be noted the total output has amounted to about 8,000,000 kwhr per month. This machine forms a flexible tie between the 25 and 60-cycle systems, and to some extent enables them to be operated as a single system. In addition, the machine is able to provide a substantial power factor correction as may be needed on each system. Power losses with this machine are less than $^1/_3$ of the aggregate losses of the old fre-

Table I—Electric Energy Available at Baltimore

Generating Station	Installed Capacity (Kw) 25 Cycles	Installed Capacity (Kw) 60 Cycles	Approximate Capacity Available in Baltimore Steam and Hydro (25 and 60 Cycles)
Westport (steam)	125,000	40,000	145,000
Pratt St. (steam)	20,000		Reserve
Gould St. (steam)		72,000	72,000
Total Balto. (steam)	145,000	112,000	217,000
Holtwood (hydro)	87,000	24,000	70,000
Holtwood (steam)		20,000	
Safe Harbor (hydro, 4 units)		112,000	108,000
Total hydro			178,000

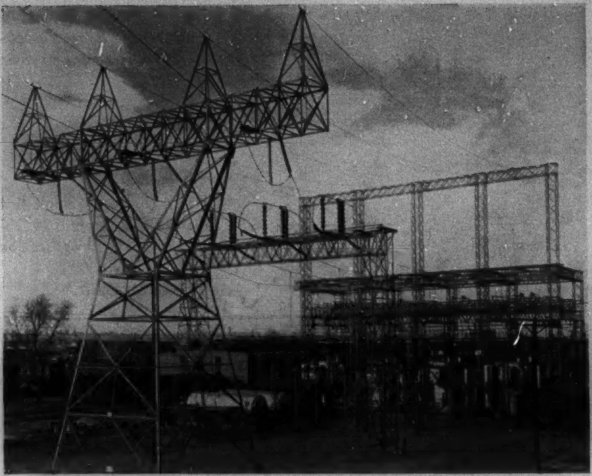


Fig. 5. General view of the Westport 230/33-kv substation showing the Safe Harbor line entering from the left

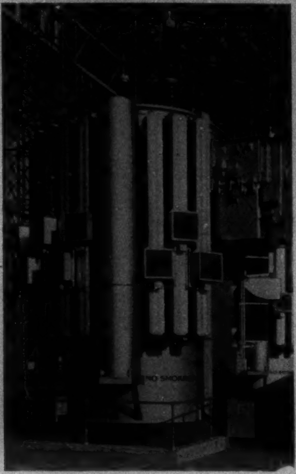


Fig. 6. One of the 230-kv 42,000-kva surge-proof transformer units

quency changers formerly operating in the substations, resulting in a saving in losses in the first 5 months of 1932 of 6,681,500 kwhr. At this writing the machine has been operated continuously without a shutdown for about 6 months.

BALTIMORE TRANSMISSION AND DISTRIBUTION SYSTEM

A single-line diagram indicating the main connections of the 60-cycle transmission and distribution systems is shown in Fig. 3. The present Safe Harbor line reaches Baltimore at Westport, at the west end of the system, while the future line will connect to the east end of the system at Riverside. A large part of the energy stepped down at Westport is distributed through 13-kv underground cables to various substations. Thus it was necessary to determine whether to step down the Safe Harbor power to 13 kv directly or to use an intermediate bus of 33 kv. The latter plan was decided upon because it was more economical for transmitting large blocks of power to the Gould Street station, and in the future to the Riverside station, the terminal of the second Safe Harbor transmission line. To step down directly to 13 kv would have overtaxed the capacity of the 13-kv switches in power stations on the system.

In Fig. 4 may be seen a single-line diagram of the incoming line, step-down transformers, and 33-kv substation. The 33-kv side of the transformer bank is connected to 2 sets of buses from which power is delivered through 4 interstation tie feeders each of 36,000-kva capacity. Each tie consists of 3 350,000-cir-mil 3-conductor cables of the shielded type.

Two of these interstation ties connect through oil filled reactors to the Gould Street station about 7,300 ft distant (see Fig. 3). These cables run under water for a distance of about 2,240 ft. East of Gould Street station 12 submarine cables have been laid across the channel from Fort McHenry to Lazaretto Point, with an average length of 2,130 ft each.

These cables were laid in a trench 47 ft below mean low tide and covered with 5 ft of fill for protection. Only 3 of the 12 cables are now carrying load, the remainder being designed to form a future tie from Gould Street through to the Riverside station and the second Safe Harbor line.

At Gould Street 33-kv energy is stepped down to 13 kv in 2 transformer banks. These consist of 3-phase self-cooled auto transformers, of the conservator type, having a reactance of about 4 per cent; they are rated at 36,000 kva each, and are equipped with tap changers to operate under load.

The other 2 interstation ties from the 33-kv substation at Westport connect to the Westport 13-kv switch house through 2 36,000-kva transformers similar to those at Gould Street. These transformers are built with the necessary reactance to limit short circuit current, no reactors being installed in this connection. These 4 36,000-kva connections have a combined capacity sufficient to handle the full output of the 126,000-kw 230-kv step-down transformers. Safe Harbor energy transmitted through the tie lines to Gould Street is distributed through 13-kv cables as shown in Fig. 3 to other stations on the system. The 66-kv ring around Baltimore is fed from the Westport 13-kv bus through step-up transformers as may be noted.

SUBSTATION AT WESTPORT

A general view of the Westport substation may be seen in Fig. 5, where the incoming line from Safe Harbor is shown at the left. This view shows also the oil storage tanks and oil filter house close by, with the 4 main transformers and control house at the right. A close-up of one of the main transformers is shown in Fig. 6.

Each of the 4 main transformers is a single-phase 60-cycle 28,000 kva self-cooled shell type unit, one of which is held in reserve. Radiators on each transformer are provided with small blowers which give an overload capacity of 50 per cent or 42,000 kva. This air blast is controlled automatically from the transformer oil temperature by "mercoid" switches, which start and stop the fans as required. The spare transformer is connected so that it can be switched in to replace any of the other units in from 8 to 10 min. Each transformer is provided with equipment for changing taps under load so that the system voltage may be maintained smoothly over all load conditions. These taps are on the 230-kv winding adjacent to the neutral point and give a voltage range of 20 per cent. Each transformer has a 13.8-kv tertiary winding of 9,800-kva capacity, Δ-connected. This winding aids in stabilizing the system neutral and in suppressing third harmonic voltages.

These transformers are connected Y-Y with solidly grounded neutral. Bushings are of the condenser type and include a potential device for operating neon lights and relays. In each transformer differential protection is provided for each of the 3 windings so that failure in any winding will cause the transformer bank to be cut out promptly by automatic switch operation on the 33-kv side. The 230-kv side would be cleared by the overload tripping of switches at Safe Harbor. The secondary windings of these transformers are divided into 2 33-kv parts each of half rated capacity, giving the equivalent of 2 banks of step-down transformers; this makes for reliability and reduces the short circuit currents. The transformers are guaranteed to endure full short circuit current for 5 sec without damage.

SURGE-PROOF CONSTRUCTION OF TRANSFORMERS

Much has been written concerning the surge-proof design of these transformers which were the first very large transformers to which this design was applied. The 2 outstanding features of this design are (1) the proportioning of the high tension coils to distribute electrostatic strain evenly over the winding, and (2) the boxing of each coil in insulation to eliminate creepage surface. It is unnecessary to repeat here what has appeared in the technical press. It is hoped that they are practically immune to lightning damage, having been subjected on test to an impulse voltage surge of 3 million volts without damage.

LIGHTNING ARRESTERS

Lightning arresters are provided to relieve surges on the line. (See Fig. 7.) The upper part of each arrester, to which the line is connected and which consists of sphere gaps, is suspended from overhead steelwork through suitable insulators; the lower section consists of porous block elements. The normal rating of the arresters is 200 kv; if, however, the 33-kv bus voltage rises 25 per cent, an additional section of arrester elements normally short circuited are cut in automatically, these additional elements giving the arrester a rating of 240 kv. The purpose of this automatic device is to prevent discharge of the arrester should the generators at Safe Harbor overspeed.

Spill gaps are provided to relieve any high voltage surge that the arrester cannot dissipate; these gaps have a 3-ft diameter top ring, a 5-ft diameter bottom ring, and a gap length of 64 in. These spill gaps will flash over before the transformer bushing flashes. In this regard it may be interesting to know that the various insulation elements in the station are coordinated, the breakdown strength beginning with the lowest, being as follows: lightning arrester, spill gap, transformer bushing, and finally the transformer itself.

CIRCUIT BREAKERS AND CONTROL

No oil circuit breakers are provided on the 230-kv incoming line. However, sufficient space has been left so that these can be installed later should they be required when the second line is built from Safe Harbor. All switching consequently is done on the low voltage side of the transformers. These switches are of the 3-phase solenoid-operated type and are rated at 34.5 kva, and 1,200 amp; they are guaranteed to clear the circuit in not more than 8 cycles. Contacts of these switches are of the deion type.

Dual control is provided for the Westport 33-kv station. The operating and load dispatcher's rooms in the Westport generating station are about 900 circuit ft distant from the substation. This long

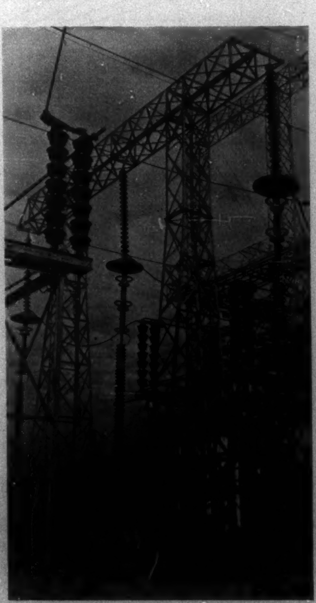


Fig. 7. Lightning arresters connected to the Safe Harbor 230-kv line at Westport substation

run would have introduced too great a voltage drop for current transformer and control circuits connected in the usual manner; for that reason one control center was established in the outdoor station to serve as the terminal point of the secondaries of the current and potential transformers and of the control wires from oil circuit breakers and other equipment. The second control point is in the switchboard operating room of the generating station. Control operations from this point are carried on over special control cables installed between the operating room and the control center in the outdoor station, which connect to relays operating d-c control circuits to the equipment. The control house contains also standard instruments and meters for measuring the circuit outputs, and special relays and totalizing instruments which pass on the principal indications to the operating room in the power house.

VOLTAGE REGULATION OF BALTIMORE LOAD

One fundamental requirement of the voltage regulation in Baltimore is to supply the 13-kv customers with approximately constant voltage. Many of these customers are supplied by radial cables from substations; others by cables from generating stations. Past as well as present practice is to regulate the 13-kv buses at the Westport and Gould Street generating stations so that the voltage at customers' premises should not vary materially. Satisfactory regulation of the Safe Harbor energy is obtainable by suitable taps on the 230/33-kv transformers, which, as stated previously, are changed under load.

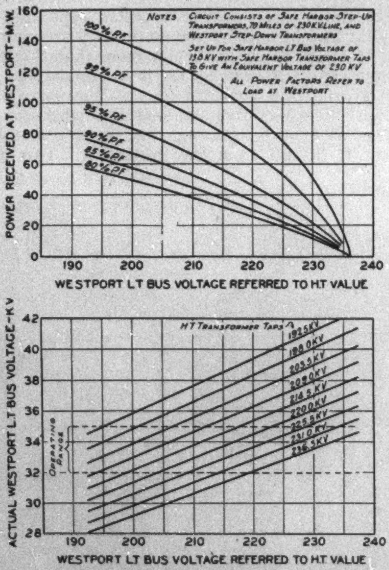


Fig. 8. Voltage regulation curves for Safe Harbor-Westport 230-kv line

In Fig. 8 are shown a typical sheet of curves developed to determine the best ratio for step-down transformers and the proper taps for obtaining desired voltages under all load conditions and varying power factors. Assuming normal generator voltage at Safe Harbor the upper curves were laid out for one of the transformer taps at Safe Harbor, with ordinates of power received at Westport; abscissas were Westport low potential bus voltage referred to high voltage values. Actual voltages then were calculated following Nesbits "Electrical Characteristics of Transmission Circuits" and using Wilkinson's formula and the circle diagram. Such calculations were made for various power factors from 100 to 80 per cent. These curves give the terminal voltage at Westport for any load on the transmission line and for any particular power factor. The curves show also the regulation of the transmission line including the step-up bank at Safe Harbor and step-down bank at Westport. It is of interest to note the greatly increased amounts of power that can be transmitted at high power factor for the same voltage drop.

In order to forecast actual Westport low voltage bus potentials the curves just in the lower part of Fig. 8 are developed with actual voltages as ordinates and the same abscissas as the upper curves. Each of these straight lines represents conditions for one transformer tap.

TESTS OF 230-KV TRANSMISSION LINE

After the Safe Harbor-Baltimore line was completed and before the first generator was available at Safe Harbor, tests were made, in cooperation with engineers of the Pennsylvania Water and Power Company, from the Baltimore end to determine the electrical constants of the line; these were made for the purpose of analyzing and predicting the performance of the line under normal and abnormal conditions. Measured values checked closely with the calculated or theoretical values. A few of the interesting test results are as follows:

1. Insulation resistance of the 3 conductors to ground was in excess of 200 megohms.

2. The d-c resistance of each conductor at 25 deg C was found to be 8.0 ohms; the a-c 60-cycle resistance per conductor at 25 deg C was found to be 8.7 ohms. The difference between the a-c and d-c resistances is due principally to hysteresis and eddy currents or iron losses in the steel conductor core.

3. The d-c resistance of the earth and ground wire return was found to be 0.55 ohms, indicating low ground resistance at both ends of the line. Resistance of the 2 ground wires in parallel is about 16 ohms so that in this test very little current passed through the ground wires.

4. Effective 60-cycle a-c resistance of the earth and ground wire return was found to be 6.43 ohms. This value is much greater than the d-c resistance because the relation of the leakage impedance of the line conductors and ground wires and the mutual impedance of the earth.

5. Balanced impedance per phase at 25 deg C was found to be 59.7 ohms per conductor.

6. Zero phase sequence impedance was found to be 125.4 ohms. This value is 3 times the impedance measured by taking the 3 conductors in parallel with the return circuit through the earth and overhead ground wires. This value is of real importance in the calculation of ground faults, in the solving of inductive coordination

problems and in determining the stability of the line under various fault conditions. It is of interest to note also that this value is 210.4 per cent of the balanced or so-called positive phase sequence impedance per phase.

7. Open-circuit line excitation at 60 cycles and 230 kv required 51.1 amp or 20,400 kva. This condenser effect is an important element in the control of power factor and line voltage. The high charging kva of such a transmission line has the well-known result of increasing voltage on the generators for a given field current due to the boosting effect of armature reaction of currents at leading power factor. If the transmission line be excited by a single generator, this condenser effect may lead to excessive line voltages unless the field current is held to the necessary low value. The Safe Harbor generators are designed with this in view but in exciting the line from the Baltimore generators the excitation must be controlled to the desired low value.

Power Limit of a Transmission System

This article presents a practicable and comparatively simple means of determining the ability of an electric power transmission system to withstand any type of short circuit at any single point of the system without losing synchronism. The method is one that enables an engineer without much special training in handling stability problems to obtain quite accurate solutions with a reasonable expenditure of time.

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A SIMPLE and accurate method of calculating the power limit of a transmission system under dynamic conditions is presented; rotor movements of the synchronous machinery at each end of the line are taken into account, both during and after the short circuit. From such calculations curves may be constructed to show the permissible duration of any type of short circuit at any single point in the system as a function of the load being carried previous to the short circuit. Circuit conditions before and after the short circuit need not be alike; that is, certain sections of line can be considered switched out as would be the case in order to clear the short circuit.

Calculations of this nature find their greatest usefulness in the design of long distance high voltage transmission lines where the principal limitation in design and performance is power limit or stability. By their use, the following important choices are facilitated:

1. Selection of proper speed of oil circuit breakers.
2. Selection of most advantageous characteristics of other equipment such as generators and transformers, by indicating to what extent equipment of especially low reactance should be used.
3. Decision as to the number of sectionalizing points that may be necessary on a given transmission line.
4. Conclusion as to the proper load rating of the transmission system.

FUNDAMENTAL PRINCIPLES

A transmission system is essentially 2 groups of synchronous machinery, electrically connected together by a transmission line, and having loads taken off at points between the 2 groups of generators (or generator and motor or condenser) and usually quite close to those at the receiving end. When a short circuit occurs, the electrical output of each of the 2 groups is changed immediately. However, as the governing mechanism of the generators and the external torque requirements of the motors or synchronous condensers do not change immediately, there is a difference between the externally applied shaft torque and the internal electrical torque. The difference between these 2 values, for a given group, causes it to accelerate or retard as the case may be. At the conclusion of the short circuit, the machine voltages have new angular relations which cause the transmission of synchronizing power from one group to the other. This power may have to be transmitted over a circuit of changed constants because of the switching that took place to eliminate the short circuit. It is necessary to determine whether the machine rotors have swung beyond angles for which the synchronizing power is adequate to control the mechanical oscillations of the synchronous machines.

Power relations between the machines or between either machine and the point of short circuit, can be expressed in terms of the voltages at those various points, the angles between the voltages, and the general circuit constants of the circuit connecting them. The most familiar form of expressing this relationship is the power angle diagram, where the power transmitted between 2 points of constant voltage is given as a function of the vector angle between the voltages.

In the power angle diagrams for this article the generator voltage is assumed to be that which includes the terminal voltage and the transient reactance drop. It is assumed, for the period of the disturbance, that this voltage remains constant. This assumption is in accordance with that made by most writers on the subject of stability. The reference voltage will be that at the point of short circuit, previous to the short circuit.

To facilitate the description of the phenomena, a 3-phase fault will be used as an example. In Fig. 1, curve *A* is a power angle diagram showing the

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Based upon a paper "Calculation of Dynamic Power Limit of Transmission System During Three-Phase Faults" originally presented at a meeting of the A.I.E.E. Los Angeles Section, Feb. 17, 1931, and subsequently awarded the 1931 A.I.E.E. Pacific District prize for best paper. Since its original presentation this paper has been revised and its scope extended. *Not published in pamphlet form.*

power sent from the internal voltage of the generator at the sending end of the line to the point of short circuit, before the disturbance. The values are on a per unit basis, which is similar to a percentage basis except that the decimal value is used. Curve *B* shows a similar relationship between the synchronous machine at the receiving end and the point of short circuit. Curves *C* and *D* show the sending and receiving-end power angle diagrams for power transmitted from the sending machine to the shaft of the receiving machine after the short circuit is cleared. It can be shown that the vertical offsets, from the zero axis, of the two cosine curves *A* and *B* correspond to the sending-end power during a 3-phase short circuit at the receiving end. Such values are designated by the horizontal lines *ef* and *gh*. Similar diagrams can be drawn for other types of short circuits.

Under normal load, steady conditions, the synchronous machine voltages and rotors will take relative positions corresponding to certain calculable angles with respect to the reference voltage, and will require certain shaft torques to maintain the assumed flow of power. Such points are indicated in Fig. 1 by *a* and *b*. Point *b* is on the zero line because the machine was a synchronous condenser and had no externally applied shaft torque.

During the short circuit, a torque equal to the difference between the shaft input and the electrical output, which for the 3-phase short circuit is represented by the distance between point *a* and line *ef*, is acting to accelerate the sending-end generator. Similarly a torque represented by the distance between point *b* and line *gh* is acting on the receiving machine. In this particular example it is retardation. For a given duration of short circuit and known moments of inertia of the rotors, the rotor movements can be calculated. Their new angles are designated as δ_1' and δ_1'' on Fig. 1. At this time the machines can be assumed to be connected together by a new circuit performing in accordance with curve *C*. The angle between rotors is $\delta_1' - \delta_1'' = \delta_1$. At this angle the output of the sending-end machine is greater than initially. This output tends to slow down the leading machine and speed up the lagging machine or to bring them closer to synchronism.

While the speed is changing, the machines have certain velocities with respect to each other. In reaching a state of synchronism, with a constant

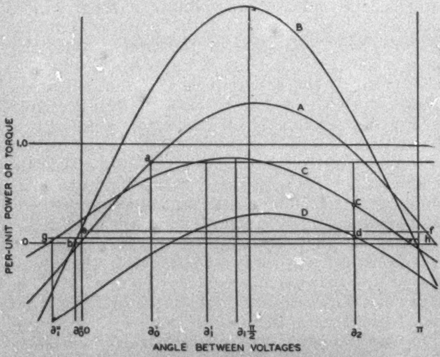

Fig. 1. Power-angle or torque-angle diagram of a typical transmission system

Table I—Calculation Form to Test Stability of Transmission System for 3-Phase Short Circuits

1.	E_g	= 1.020
2.	E_r	= 1.000
3.	E_c	= 1.283
4.	b_{L1}	= 0.0657
5.	b_{L2}	= 0.7815
6.	$\sqrt{b_{L1}^2 + b_{L2}^2}$	= 0.7845
7.	*4/6*	= 0.0838
8.	$\theta_{Lb} = \cos^{-1}$ *7*	= 1.4867
9.	b_{R1}	= −0.0199
10.	b_{R2}	= 0.5500
11.	$\sqrt{b_{R1}^2 + b_{R2}^2}$	= 0.5503
12.	*9/11*	= 0.0362
13.	$\theta_{Rb} = \cos^{-1}$ *12*	= 1.6070
14.	b_{C1}	= −0.3098
15.	b_{C2}	= 1.6740
16.	$\sqrt{b_{C1}^2 + b_{C2}^2}$	= 1.7025
17.	*14/16*	= −0.1820
18.	$\theta_{Cb} = \cos^{-1}$ *17*	= 1.7538
19.	Sin θ_{Cb} = *15/16*	= 0.9833
20.	Sin² θ_{Cb} = *19²*	= 0.9668
21.	Cos² θ_{Cb} = *17²*	= 0.03312
22.	M_g	= 18.29
23.	M_c	= 3.325
24.	*1/(22 × 6)*	= 0.0710
25.	*1/(22 × 16)*	= 0.0327
26.	*3 × 25*	= 0.0420
27.	*3/(23 × 11)*	= 0.7015
28.	*3/(23 × 16)*	= 0.2266
29.	*1 × 28*	= 0.2312
30.	d_{L1}	= 0.8872
31.	d_{L2}	= 0.0180
32.	*30 × 4*	= 0.0583
33.	*31 × 5*	= 0.0141
34.	*32 + 33*	= 0.0724
35.	d_{R1}	= 1.046
36.	d_{R2}	= 0.057
37.	*35 × 9*	= −0.021
38.	*36 × 10*	= 0.031
39.	*37 + 38*	= 0.010
40.	d_{C1}	= 0.8401
41.	d_{C2}	= 0.3176
42.	*40 × 14*	= −0.2602
43.	*41 × 15*	= 0.5318
44.	*42 + 43*	= 0.2716
45.	a_{C1}	= 1.453
46.	a_{C2}	= 0.750
47.	*45 × 14*	= −0.451
48.	*46 × 15*	= 1.256
49.	*47 + 48*	= 0.805
50.	δ_0'	= 0.6590
51.	δ_0''	= −0.0593
52.	$\delta_0 = \delta_0' - \delta_0''$	= 0.7183
53.	$\delta_0' + \theta_{Lb}$ = *50 + 8*	= 2.1457
54.	Cos$(\delta_0' + \theta_{Lb})$	= −0.5435
55.	$\delta_0'' + \theta_{Rb}$ = *51 + 13*	= 1.5477
56.	Cos$(\delta_0'' + \theta_{Rb})$	= 0.0231
57.	*26 + 29*	= 0.2732
58.	*26 − 29*	= −0.1892
59.	+ *2 × 24 × 54*	= −0.03862
60.	− *2 × 27 × 56*	= −0.01620
61.	− *1 × 24 × 34/6*	= −0.00668
62.	+ *3 × 27 × 39/11*	= 0.01668
63.	+ *1 × 25 × 44/16*	= 0.00532
64.	− *3 × 28 × 49/16*	= −0.13750
65.	Σ*59* to *64*, inc.	= −0.17700
66.	*57²*	= 0.0746
67.	*58²*	= 0.0358
68.	*65²*	= 0.03132

69.	*67 × 21*	=	0.001186	
70.	*66 × 20*	=	0.0722	
71.	*69 + 70*	=	0.07339	
72.	*71 − 68*	=	0.04207	
73.	*69 × 72*	=	0.0000499	
74.	± $\sqrt{73}$	=	0.00706	−0.00706
75.	*65 × 57 × 19*	=	−0.0476	
76.	± *74 − 75*	=	0.0547	0.0405
77.	*76/71* = Sin δ_2	=	0.746	0.552
78.	$\delta_2 = \sin^{-1}$ *77* $>\pi/2$	=	2.2996	2.5567
79.	$\delta_2 + \theta_{Cb}$ = *78 + 18*	=	4.0534	4.3105
80.	$\delta_2 - \theta_{Cb}$ = *78 − 18*	=	0.5458	0.8029
81.	Cos $(\delta_2 + \theta_{Cb})$	=	−0.6124	−0.3911
82.	Cos $(\delta_2 - \theta_{Cb})$	=	0.8543	0.6943
83.	*26 × 81*	=	−0.0257	−0.0164
84.	*29 × 82*	=	0.1973	0.1605
85.	*83 − 84 = 65*	=	−0.2230	−0.1769
86.	Sin $(\delta_2 + \theta_{Cb})$	=		−0.9201
87.	Sin $(\delta_2 - \theta_{Cb})$	=		0.7192
88.	*59 + 60*	=		−0.05482
89.	*88²*	=		0.00300
90.	f = freq.	=		50

Note: From item *74* to *85* tabulate 2 sets of values. Choose both values of δ_2, item *78* in the second quadrant, that is, greater than $\pi/2$. In order to determine which is correct, note which one satisfies condition in item *85*. Use the correct value for remaining work.

91.	t	=	0.29	0.33	0.337
92.	$\pi f t^2$	=	13.21	17.11	17.82
93.	− *92 × 88*	=	0.7238	0.9380	0.9762
94.	δ_1 = *93 + 52*	=	1.4421	1.6563	1.6945
95.	$\delta_1 + \theta_{Cb}$ = *94 + 18*	=	3.1959	3.4101	3.4483
96.	$\delta_1 - \theta_{Cb}$ = *94 − 18*	=	−0.3117	−0.0975	−0.0593
97.	Sin $(\delta_1 + \theta_{Cb})$	=	−0.0543	−0.2650	−0.3020
98.	Sin $(\delta_1 - \theta_{Cb})$	=	−0.3068	−0.0975	−0.0593
99.	*87 − 98*	=	1.0260	0.8167	0.7785
100.	*86 − 97*	=	−0.8658	−0.6551	−0.6181
101.	$\delta_2 - \delta_1$ = *78 − 94*	=	1.1146	0.9004	0.8622
102.	*101 × 65*	=	0.1972	−0.1592	−0.1525
103.	*29 × 99*	=	0.2372	0.1890	0.1800
104.	− 26 × 100	=	0.0364	0.0275	0.0260
105.	*102 + 103 + 104*	=	0.0764	0.0573	0.0535
106.	*92 × 89*	=	0.0396	0.0514	0.0535
107.	t for *105 = 106*	=			0.337

Note: *Italic* numbers refer to item numbers.

Table II—Calculation Form to Test Stability of Transmission System for 2-Phase-to-Ground and 1-Phase-to-Ground Short Circuits

Use Table I for first 88 items

89. b_{F1} =
90. b_{F2} =
91. $\sqrt{b_{F1}^2 + b_{F2}^2}$ =
92. $89/91$ =
93. $\theta_{Fb} = \cos^{-1} 92$ =
94. $1/(22 \times 91)$ =
95. 3×94 =
96. $3/(23 \times 91)$ =
97. 1×96 =
98. $\delta_0 + \theta_{Fb} = 52 + 93$ =
99. $\delta_0 - \theta_{Fb} = 52 - 93$ =
100. a_{F1} =
101. a_{F2} =
102. 100×89 =
103. 101×90 =
104. $102 + 103$ =
105. d_{F1} =
106. d_{F2} =
107. 105×89 =
108. 106×90 =
109. $107 + 108$ =
110. Sin 98 =
111. Sin 99 =
112. $-(59+60+61+62)$ =
113. $- 1 \times 94 \times 109/91$ =
114. $+ 3 \times 96 \times 104/91$ =
115. $112 + 113 + 114$ =
116. $- 115 \times 52$ =
117. $- 95 \times 110$ =
118. $+ 97 \times 111$ =
119. $116 + 117 + 118$ =

120. δ_1 (Assumed) =
121. $\delta_2 - \delta_1 = 78 - 120$ =
122. $\delta_1 - \delta_0 = 120 - 52$ =
123. $\delta_1 + \theta_{Fb} = 120 + 93$ =
124. $\delta_1 - \theta_{Fb} = 120 - 93$ =
125. Sin $(\delta_1 + \theta_{Fb})$ =
126. Sin $(\delta_1 + \theta_{Fb})$ =
127. $125 - 110$ =
128. $111 - 126$ =
129. $\delta_1 + \theta_{Cb} = 120 + 18$ =
130. $\delta_1 - \theta_{Cb} = 120 - 18$ =
131. Sin $(\delta_1 + \theta_{Cb})$ =
132. Sin $(\delta_1 + \theta_{Cb})$ =
133. $86 - 131$ =
134. $87 - 132$ =
135. $- 133 \times 26$ =
136. $+ 134 \times 29$ =
137. 121×65 =
138. $135 + 136 + 137$ =
139. 122×115 =
140. 95×127 =
141. 97×128 =
142. $139 + 140 + 141$ =
Vary δ_1 until $138 = 142$

143. $95 + 97$ =
144. $143 + 119$ =
145. f =
146. $(1.74)\pi f \times 143$ =
147. $\sqrt{146}$ =
148. $(1.74) \times 143 \times 144$ =
149. 115^2 =
150. $148 + 149$ =
151. $\sqrt{150}$ =
152. $(0.87) \times 143 \times 120$ =
153. $(0.87) \times 143 \times 52$ =
154. $152 - 115$ =
155. $153 - 115$ =
156. $154/151$ =
157. $155/151$ =
158. $\text{Sin}^{-1}\ 156$ =
159. $\text{Sin}^{-1}\ 157$ =
160. $158 - 159$ =
161. $160/147$ =
Duration of short circuit is given by *161*

Note: *Italic* numerals refer to item numbers.

angle between the rotors, oscillations take place; some of the energy is consumed in losses and some in changing the total system speed. The stability can be checked at the end of the first oscillation. At this point the lagging machine is farthest in angular position from the leading machine, their relative velocity is zero, and their actual velocities are alike. Simultaneously the condition also should be fulfilled that the machines have the same absolute acceleration, i. e., the same tendency to change the total system speed. This may be stated also by saying the machines have zero relative acceleration. This criterion is in accordance with that expressed previously in a paper by Summers and McClure[3] (for numbered references see list at end of article), namely, that "the machines have come to rest with respect to each other before the acceleration becomes finally zero." The limit is of course as their relative acceleration becomes zero.

During the short circuit, the rotors reached an angular separation of δ_1, and their relative angular velocity increased from zero to some value designated as ω_1. In the interval following the removal of the short circuit and lasting until the end of the first oscillation, when the rotors again have the same velocity, their relative angular velocity has changed from ω_1 to zero. Equations expressing the accelerations during both of these intervals can be set up and solutions for ω_1 made. The accelerating torques during the second interval are shown in Fig. 1 as the vertical distance between curve C and line ac; and the distance between curve D and horizontal line through point b, which in this case is the zero axis. The particular values used are those to the right of the angle δ_1, where this type of acceleration begins.

Referring to Fig. 1, curve C, this means that for stability the oscillation should not cause the machines to swing beyond points c and d at the angle δ_2 where the relative acceleration of the machines is zero. At δ_2 the torque acting on the sending-end machine is represented by the distance between c on curve C and the horizontal line through initial load point a. The torque acting on the receiving machine is given by the distance between point d on curve D and the horizontal line through its initial load line, which in this case is the zero line. Accelerations of these machines are equal when their torques divided by their inertia constants are equal; δ_2 is calculated to fulfill this condition.

CALCULATION FORM

Calculations for a 3-phase fault are made more readily by use of the forms given in Table I. For unbalanced faults use the supplementary form given in Table II. In these forms all voltages and the components of the general circuit constants are on a per-unit basis. All angles are expressed in radians. Loads are represented by shunt admittances and are combined into the general circuit constants. Duration of the short circuit is expressed in seconds.

A trial calculation is made in Table I for a specific duration of short circuit. If item 101 is larger than item 103 the system is stable for that time. If an accurate solution is required, different assumptions of time are made until those 2 items are the same. This requires 3 or 4 approximations. Only a few of the items change as the time is changed so that successive approximations are not as tedious as the first.

The list of symbols used is as follows:

E_g = internal voltage of sending-end generator.
E_c = internal voltage of receiving-end generator or motor.
E_r = reference voltage at point of short circuit.
f = system frequency in cycles per second.
t = duration of short circuit in seconds.
A_L, B_L, C_L, D_L = general circuit constants of circuit between E_g and E_r.
A_R, B_R, C_R, D_R = general circuit constants of circuit between E_c and E_r.
A_C, B_C, C_C, D_C = general circuit constants of circuit between E_g and E_c, after the short circuit.
A_F, B_F, C_F, D_F = general circuit constants of circuit between E_g and E_c at the time of the fault, and including the fault impedance in accordance with symmetrical component theory.

(The preceding 4 groups of constants are made up of components designated similar to the following: $B_R = b_{R1} + jb_{R2}$.)

δ_0' = initial angle between E_g and E_r.
δ_0'' = initial angle between E_c and E_r.
δ_0 = initial angle between E_g and E_c.
δ_1' = angle between E_g and E_r after short circuit.
δ_1'' = angle between E_c and E_r after short circuit.
δ_1 = angle between E_g and E_c after short circuit.
δ_2 = angle between E_g and E_c after short circuit and where relative acceleration of sending and receiving machines is zero.

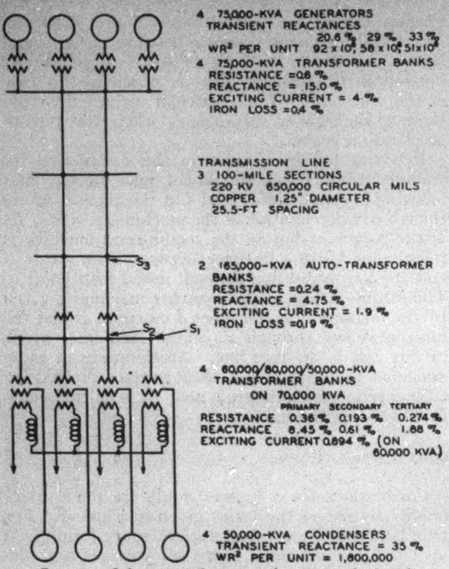
4 75,000-KVA GENERATORS
TRANSIENT REACTANCES
20.6 % 29 % 33 %
WR² PER UNIT 92 x 10⁶, 58 x 10⁶, 51x10⁶
4 75,000-KVA TRANSFORMER BANKS
RESISTANCE =0.6 %
REACTANCE = 15.0 %
EXCITING CURRENT = 4 %
IRON LOSS =0.4 %
TRANSMISSION LINE
3 100-MILE SECTIONS
220 KV 650,000 CIRCULAR MILS
COPPER 1.25" DIAMETER
25.5-FT SPACING
S3
2 165,000-KVA AUTO-TRANSFORMER BANKS
RESISTANCE =0.24 %
REACTANCE = 4.75 %
EXCITING CURRENT = 1.9 %
IRON LOSS =0.19 %
S2
S1
4 60,000/80,000/50,000-KVA TRANSFORMER BANKS
ON 70,000 KVA
PRIMARY SECONDARY TERTIARY
RESISTANCE 0.36 % 0.193 % 0.274 %
REACTANCE 8.45 % 0.61 % 1.88 %
EXCITING CURRENT 0.894 % (ON 60,000 KVA)
4 50,000-KVA CONDENSERS
TRANSIENT REACTANCE = 35 %
WR² PER UNIT = 1,800,000

Fig. 2. Schematic diagram of a typical double circuit transmission system

Inertia constants of the sending-end and receiving-end rotors are designated by M_G and M_C and are found from the equation

$$M = \frac{0.462WR^2(\text{rpm}/1000)^2}{\text{base} \quad \text{kw}}$$

where the WR^2 is expressed in pound-feet squared.[1] The remainder of the symbols are obvious from the operations directed in Table I. Where mathematical operations are designated by italic numerals, such as *32* + *33*, the quantities designated by those item numbers are to be used in that manner.

General circuit constants are calculated for the circuit between the internal voltage of each group of machines and the point of short circuit, with the short-circuit point being considered the receiving end. In calculating these constants all load admittances are included. If switching occurs to clear the short circuit thereby changing these constants, these new constants also are calculated. Constants of the final circuit between the 2 internal voltages then are calculated. It is convenient to do this by regarding the system as the 2 previously calculated systems in series. However, as the receiving ends of the 2 circuits are connected together, before combining them it is necessary to interchange the *A* and *D* constants of the circuit that is in the wrong relation, the receiving-end circuit. It can be demonstrated that when the receiving and sending relationships of a general circuit are interchanged, the *A* and *D* constants are interchanged.

By proper use of the foregoing constants, or by any other method of line drop calculation, the initial internal voltages of the machines are determined with respect to the voltage E_r at the point of short circuit. The voltage angles also are determined, in comformance with initial assumptions of output.

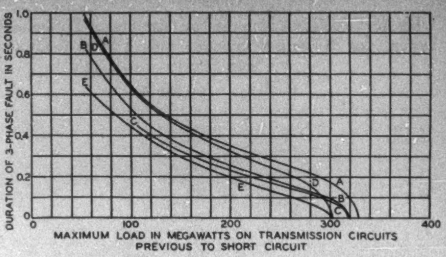

Fig. 3. Stability curves for pair of 300-mile 50-cycle 220-kv transmission curcuits in Fig. 2

A. Short circuit at S_1; no line section lost; generator reactance 20.6%
B. Short circuit at S_1; no line section lost; generator reactance 29.0%
C. Short circuit at S_1; no line section lost; generator reactance 33.0%
D. Short circuit at S_2; one line section lost; generator reactance 20.6%
E. Short circuit at S_3; one line section lost; generator reactance 20.6%

Substitutions then are made in the calculation form as shown in Table I. For item 76 2 values are possible depending on which sign is used. Two values result in items 77 and 78. Choose δ_2 for item 78 so that it is in the second quadrant, that is greater than $\pi/2$. Also choose δ_2 so that it satisfies the condition that *26* × *81* − *29* × *82* = *65*; this is a quick way of checking which is the proper solution to use.

Finally if item 105 is greater than item 106 the system is stable. By successive approximations the exact duration of short circuit can be determined for which item 105 equals item 106 and instability occurs. Changes in load necessitate changes in circuit constants unless they are shaft loads on the receiving machine, but changes in duration of short circuit can be made quite readily and will affect only a limited number of items.

Some illustrative calculations are included in Table I. The circuit involved is that given on Fig. 2. Circuit constants are as given in Table I. The base chosen was 250,000 kva, and the initial voltage at the high voltage bus on the receiving end was 220 kv. The performance of such a system under different conditions is given in Fig. 3.

The method outlined in this article is one that enables an engineer without much special training in handling stability problems to obtain reasonably quickly solutions for the simple system which are quite accurate for all types of single location short circuits.

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3. PROGRESS IN THE STUDY OF SYSTEM STABILITY, Appendix II, I. H. Summers and J. B. McClure. A.I.E.E. TRANS., v. 49, 1930, p. 132–61.

News
Of Institute and Related Activities

The Institute's 49th Annual Summer Convention

CHICAGO during Engineers' Week, June 26–30, 1933, at the Century of Progress International Exposition, was marked by a predominance of technologists, particularly around the leading hotels where congregated the several thousand individuals attempting to attend one or more of the several technical and scientific conclaves. The many delegates and visitors present from various nations throughout the world created also a distinctly international atmosphere, and brought into the sessions some points of view not usually available.

Among the noteworthy characteristics of the week's activities were the many joint sessions held among the several societies. These joint sessions together with the almost unlimited opportunities for attendance at technical sessions of several different organizations, made possible wide individual contact and a great variety of subject matter. And of course there were the special features of Engineers' Day at the Century of Progress Exposition in addition to the ever-present lure of 80-odd miles of exhibits and attractions, serious and frivolous, technical and non-technical.

The Institute's activities centered at the Edgewater Beach Hotel, where meeting facilities were excellent and where those in attendance enjoyed the undeniably attractive features of a resort hotel, in combination with the convenience of a city location.

ANNUAL MEETING

The initial session of the Institute's 49th summer convention was held Monday morning. After being called to order by H. H. Henline, national secretary, the address of welcome was delivered by H. B. Gear, chairman of the engineering societies committee of the Century of Progress Exposition, and chairman of the Institute's general convention committee. This was followed by the annual business meeting of the Institute, with President H. P. Charlesworth presiding. Mr. Henline presented a résumé of the annual report of the board of directors, reflecting the essential features of the Institute's activities during the past year; he presented also, at the request of President Charlesworth, the report of the committee of tellers. As detailed announcements of the annual meeting and other activities appeared in ELECTRICAL ENGINEERING for July 1933, p. 504–5, they will not be elaborated on here.

President Charlesworth then presented the president's badge to President-Elect J. B. Whitehead, who, in his brief address of response, stated in part "......of course it is easy to see that most of the problems of the Institute, and those of the president and the board of directors, can be segregated, I think, into 2 classes. The first of these is the preservation of the ideals and the traditions of the Institute, the maintenance of a high scientific standard of aims and purpose, and the elevation of the profession of electrical engineering. The second class of problem has to do with the material methods and resources with which those higher purposes are carried out. As we look at the Institute ...... in these troublous times, one thing upon which we can congratulate ourselves is that those higher purposes of the Institute are not affected really ...... by ...... introductions of economic and industrial prosperity or depression. They are questions in which each ...... of us can maintain the standards and purposes and ideals of the Institute, and therefore we need not be discouraged if there are difficulties associated with the material prosecution and efforts to carry on in accordance with our best traditions."

The various prizes for A.I.E.E. technical papers for 1932 were then presented after President-Elect Whitehead's address. Announcement of these prizes was published in ELECTRICAL ENGINEERING for June 1933, p. 424–5, and July, p. 504.

LAMME MEDAL PRESENTED

One of the features of the annual meeting was the presentation of the 1932 Lamme Gold Medal to Dr. Edward Weston, past-president (1888–89) and long-time member of the Institute. Unfortunately, Doctor Weston's health and advanced age (83) prevented his attendance in person. Consequently, his son, Mr. Edward F. Weston, received the medal and certificate for him, following the remarks of Past-President A. E. Kennelly, who presented a brief biographical sketch of Doctor Weston's technical activities. In his remarks of appreciation, Mr. Weston cited the fact that his father had been active and had received recognition in chemical and other technical fields, and stated that this recognition by the Institute of his father's contribution to the electrical field was particularly appreciated by his father because it rounded out the recognition of his long scientific activities.

NEW HONORARY MEMBERS ANNOUNCED

As announced in the July issue of ELECTRICAL ENGINEERING, 6 eminent members

Members of the Institute attending the annual summer convention held as part of Engineers' Week at the Chicago World's Fair witnessed many striking scenes, such as the one shown above. This is a general night view of the Exposition grounds looking southeast from the 200-ft level of the "sky ride." In the foreground is the hall of science. Other buildings pictured are the east tower of the "sky ride," the hall of social science, the communication building, the electrical building, the enchanted island, and the horticultural building recently were elected to honorary membership in the Institute. Of these 6 only 3, W. L. R. Emmet, A. E. Kennelly, and E. W. Rice, Jr., were able to be present to receive their honors personally. Mr. Emmet in his response briefly outlined some of his most recent work in connection with the development of the mercury turbine. He stated that experimental and development work now had progressed to the point that enabled him to predict great commercial possibilities for the application of the mercury cycle in steam power plants. As an example, he cited the fact that on a ship like the S.S. Bremen, the application of a mercury boiler would "save $^2/_3$ of the machinery space, and save more than $3,000 per year in fuel costs, even with the present extremely low price of fuel oil." Doctor Kennelly in his response recalled that it was fitting that he should receive his recognition in Chicago, where, during the Columbian Exposition of 1893, the International Electrical Congress made its first important step in the internationalization of electrical units. This work has been one of Doctor Kennelly's life long avocations. Doctor Rice, in his response, cited a few figures that called to mind the tremendous advance and development made in the electrical industry during his own lifetime. He recalled attending the first International Electrical Exposition held in the United States, in Philadelphia in 1876, where the electrical exhibits consisted principally of a few crude dynamos supplying energy to some electric arc lights, and Doctor Bell's then recent invention of a device by which sound could be transmitted through electric conductors. He cited the fact that then, the total investment in all branches of the electrical industry including the telegraph system could not have exceeded $10,000,000, whereas in 1933 the investment exceeded 20 thousand million; that the investment in telephone communication systems in 1876 represented nothing but initial experimental work, whereas the 1933 investment was some 4 thousand million.

As the closing feature of the annual meeting, President Charlesworth presented the annual presidential address, choosing as his topic "The Engineer and a Century of Progress." Emphasizing the effects of science and engineering upon the life of man and the basic need for a better understanding of these effects on human society, President Charlesworth urged engineers to take a greater part in all affairs affecting human welfare. The full text of President Charlesworth's address appeared on p. 445–8 of ELECTRICAL ENGINEERING for July 1933.

TECHNICAL SESSIONS

Considering the active competition offered by the Century of Progress and by the galaxy of other technical meetings being held in Chicago concurrently, the attendance at the 6 technical sessions of the Institute's convention stands as a record of recognition of the work done by the committees and individuals who arranged and participated in the technical program. Some 32 formal technical papers and several informal technical talks were presented during the 6 sessions, the active discussion attesting to the general interest of the technical subject matter. The sessions were held 2 in parallel, Tuesday, Thursday, and Friday mornings, and it was not uncommon to find a total of 350 or more persons present. Many of these technical papers were published in the June and July issues of ELECTRCAL ENGINEERING, and interpretive abstracts of all papers not published in full in the June issue were included in that issue. Therefore, the technical program will not be discussed further here. A résumé of some of the technical discussions is published in this issue, p. 578–81.

Table I—Analysis of Attendance at 1933 A.I.E.E. Summer Convention

Classification	Chicago*	Dist. 5**	Dist. 1	Dist. 2	Dist. 3	Dist. 4	Dist. 6	Dist. 7	Dist. 8	Dist. 9	Dist. 10	For.	Totals
Members	235	81	70	82	78	23	10	35	4	10	20	0	648
Men Guests	61	14	12	20	13	3	1	5	2	1	4	4	140
Women Guests	35	18	26	32	27	13	1	14	4	6	3	0	179
Students		1											1
TOTALS	331	114	108	134	118	39	12	54	10	17	27	4	968

* Territory of the Institute's Chicago Section
** District 5, excluding Chicago

Officially recognized joint sessions, technical and otherwise, included the following:

1. A meeting held jointly with the engineering section of the American Association for the Advancement of Science, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the American Society for Testing Materials, at the Palmer House, Tuesday evening, June 27, addressed by A. P. M. Fleming on the subject "The Development of Industry and Engineering During the Century (1833–1933)." Mr. Fleming is manager of the research and educational departments of the Metropolitan-Vickers Electrical Company, Ltd., Manchester, England, and local honorary secretary for the A.I.E.E. The meeting was presided over by Dr. D. C. Jackson, vice-president A.I.E.E.

2. A meeting held jointly with the power division of The American Society of Mechanical Engineers and the hydraulics division of the American Society of Civil Engineers at the Palmer House, Thursday afternoon, June 29. This meeting was addressed by Daniel W. Mead on the subject "Résumé of the Engineering Reports on the St. Lawrence Power Development." Professor Mead is a Fellow of the Institute; professor of hydraulic and sanitary engineering at the University of Wisconsin, Madison; a member of the consulting engineering firm of Mead and Seastone of Madison, Wis., and of the consulting engineering firm of Mead and Scheidenhelm of New York, N. Y.

3. A meeting held Friday afternoon and evening, June 30, jointly with the Econometric Society, the American Society of Civil Engineers, The American Society of Mechanical Engineers, and the American Society for Testing Materials, on the subject of "Some Fundamental Problems of Mutual Interest to Scientific Economists and Engineers." The afternoon session was presided over by Irving Fisher of Yale University, New Haven, Conn., president of the Econometric Society. Addresses included: "Contributions of the Mathematician to Economics," by C. F. Roos, secretary of the Econometric Society, Washington, D. C.; "The Mathematical Theory of Rational Inference," by T. C. Fry, Bell Telephone Laboratories, Inc., New York, N. Y.; and "The Engineering Economist of the Future," by D. S. Kimball of Cornell University, Ithaca, N. Y. The evening session was presided over by Ralph E. Flanders, chairman of the American Engineering Council's committee on relation of consumption, production, and distribution. Addresses included: "Some Fundamental Problems of the Engineer," by F. B. Jewett, American Telephone and Telegraph Company, New York, N. Y.; and "The Internationalization of Scientific Knowledge as a Factor in World Economic Recovery," by A. P. M. Fleming, Metropolitan-Vickers Electrical Company, Ltd., Manchester, England.

ATTENDANCE

With an official registration of 968 persons, the attendance, although slightly lower than that recorded last year at Cleveland, was well above the average for the past 10 years, and nearly 30 per cent greater than recorded for the summer convention held in Chicago in 1924. An analysis of this attendance is given in the accompanying tabulation.

TRIPS AND ENTERTAINMENT

Recognizing that the Century of Progress Exposition would be the principal point of attraction, the local committee provided just enough additional features to provide a balanced variety. The president's reception and the informal dinner dance held Thursday evening at the Edgewater Beach Hotel turned out to be a thoroughly successful affair in spite of the emergency changes in program necessitated by a terrific storm which broke in all its fury late in the afternoon and continued on into the early evening. There were neither masters of ceremonies nor speech making of any kind, and the effect was highly commendable.

GOLF

The annual tournaments and other golfing events were played at the Westmoreland Country Club. The many attractive and valuable prizes offered by the local committee in addition to the incentive provided by the Mershon and Lee trophies brought out a total of 41 formal entrants, 15 of whom, however, did not turn in score cards. The 16 that qualified for the Mershon trophy match play included: E. S. Atkinson (M'31) Battle Creek, Mich.; A. H. Sweetman (M'18) Boston, Mass.; G. R. Canning (A'32), L. R. Keiffer (A'22) and G. A. Kositzky (F'29) Cleveland, Ohio; G. V. Smith (M'28) Mansfield, Ohio; L. W. Chubb (F'21) East Pittsburgh, Pa.; R. A. Monroe (A'30) Pittsburgh, Pa.; H. R. Summerhayes (M'16) Schenectady, N. Y.; and W. G. Copeland (M'24), H. W. Eales (F'25), F. C. Ellis (A'25), J. H. Irwin (A'20), R. I. Parker (M'20), R. W. T. Purchas (M'22), and F. O. Wollaston (A'27), Chicago, Ill. The second flight narrowed the field to Irwin, Eales, Canning, Smith, Monroe, Wollaston, Sweetman, and Keiffer, the first 4 of whom won their way into the semi-finals. Eales and Canning fought out the finals, Eales winning one up after 27 holes, thus winning the Mershon trophy and the right to have his name the second to be engraved on the 1932 trophy. This trophy was won last year at Cleveland by L. R. Keiffer of Cleveland. Mr. Keiffer was eliminated this year in the second round by G. V. Smith, one up after 20 holes. Mr. Keiffer's handicap last year was 19, this year 17; Mr. Eale's handicap was 15.

Honors in the W. S. Lee trophy competition went to G. R. Canning of Cleveland, whose handicap of 12 gave him a net score of 150 for 36 holes, against the par of 142. Mr. Canning thus won the Lee trophy and the right to have his name the second to be engraved on it. C. H. Teskey of Cleveland won the 1932 Lee trophy for the first time last year at Cleveland, with a net score of 143, handicap 7. Mr. Teskey was not present at Chicago.

Winners of prizes in special events arranged by the local sports committee were:

1st low gross, J. H. Irwin, 82
2nd low gross, J. H. Irwin, 82
1st low net, E. S. Atkinson, 72 (91 – 19)
2nd low net, R. T. Stafford, 69 (84 – 15)
Blind bogey, H. R. Summerhayes 76 (96 – 20)

The first low gross, first low net, and blind bogey were played in connection with the qualifying round for the Mershon trophy; second low gross and second low net were played in connection with the second round.

Carrying on the District team competition event inaugurated at Cleveland in 1932, the team for District No. 5, including W. G. Copeland, F. O. Wollaston, J. H. Irwin, and H. W. Eales, took first place with a total net score of 690 for 36 holes (par 568). The District No. 2 team from Cleveland took second place with a total of 721.

TENNIS

In tennis, as in golf, the local committee provided valuable prizes in addition to the Mershon trophy. All matches were played on the courts of the Edgewater Beach Hotel. With U.S. Lawn Tennis Association rules governing, all preliminary matches were decided by the best 2 out of 3 sets, the finals by the best 3 out of 5. Out of 11 formal entries, C. M. Flurscheim, Montreal, Canada; A. J. Krupy (A'26) Chicago, Ill.; H. L. Woolhiser (M'20), Winnetka, Ill.; and W. J. Morrill (A'26) Fort Wayne, Ind., won their way into the semi-finals. Krupy beat Woolhiser in the finals, thereby establishing himself as the seventh winner of the 1927 Mershon tennis trophy. Names of winners now appearing on the cup are:

1927—G. A. Swain (M'13) East Pittsburgh, Pa.
1928—P. H. Hatch (M'29) Stamford, Conn.
1929—A. J. Gowan (A'23) St. Petersburg, Fla.
1930—E. F. Lopez (M'18) Mexico City, Mex.
1931—J. K. Peck (A'27) New York, N. Y.
1932—R. A. Monroe (A'30) Pittsburgh, Pa.
1933—A. J. Krupy (A'26) Chicago, Ill.

R. A. Monroe, last year's winner and regarded as one of the most serious contenders this year inadvertently defaulted the preliminary match. E. F. Lopez of Mexico City, winner of the cup in 1930, found the Chicago heat wave too enervating and was defeated in the second round.

In addition to the other sports features provided, the local committee arranged for a ping pong tournament where out of an original entry list of 14, L. F. Hickernell (M'27) Hastings-on-Hudson, N. Y., S. C. Summerfield (A'20) Belleville, N. J., J. C. Woods (M'31) Chicago, and J. B. Cook (A'33) Chicago, won their way into the semi-finals, Cook finally winning over Summerfield in the finals.

COMMITTEES

Credit for the success of the Chicago convention, and for the splendid arrangements and facilities that were provided for the convenience and entertainment of those attending, is due to the personnel of the local committees. The general convention committee included L. A. Ferguson, *honorary chairman;* H. B. Gear, *chairman;* T. G. LeClair, *secretary-treasurer;* and K. A. Auty, W. H. Harrison, P. B. Juhnke, J. E. Kearns, W. O. Kurtz, and L. R. Mapes. The subcommittees and the affairs for which they were responsible were:

Entertainment—H. W. Eales, *chairman*, Alfred Alsaker, G. M. Armbrust, L. L. Call, W. W. Ege, and W. F. Sims.

Finance—F. H. Lane, *chairman*, W. O. Batchelder, A. M. Jackson, H. W. Young, S. G. Neiler, and W. M. Vandersluis.

Hotels and Registration—J. E. Kearns, *chairman*, L. G. Cannon, and A. J. Krupy.

Inspection Trips—E. C. Williams, *chairman*, R. J. Ferris, A. M. Garrett, and H. A. Cornelius.

Meetings and Papers—Burke Smith, *chairman*, K. W. Miller, A. Herz, and E. O. Neubauer.

Publicity—F. R. Innes, *chairman*, H. T. Burgner, R. D. Maxon, H. H. Field, and Herman Halperin.

Sports—J. H. Irwin, *chairman*, F. S. Douglass, H. L. Martin, E. C. Minteer, R. W. T. Purchas, P. L. Warren, and Dudley Young.

Transportation—R. I. Parker, *chairman*.

Women's Entertainment—Mrs. C. W. PenDell, *chairwoman*, Mrs. K. A. Auty, Mrs. H. W. Eales, Mrs. H. B. Gear, Mrs. F. R. Innes, Mrs. J. H. Irwin, Mrs. P. B. Juhnke, Mrs. J. E. Kearns, Mrs. W. O. Kurtz, Mrs. F. L. Lane, Mrs. T. G. LeClair, Mrs. L. R. Mapes, Mrs. R. I. Parker, Mrs. Burke Smith, and Mrs. E. C. Williams.

Engineers' Day at the Chicago Exposition

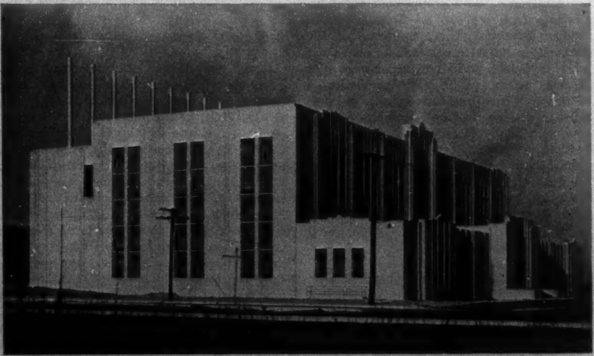
Wednesday, June 28, 1933, was designated officially by the Century of Progress International Exposition as its Engineers' Day. Hundreds of those attending the many engineering and scientific conclaves held in Chicago that week gathered Wednesday morning in the south end of the stadium at Soldiers Field, where one of the 2 joint engineering events of the day was held.

This morning event was the occasion of the presentation of the Daniel Guggenheim Medal to Juan de la Cierva for his contribution to aeronautics through the development of the autogiro. This medal is awarded for "notable achievement in the development of aeronautics."

Following a few brief words by the presiding officer, A. A. Potter, president of The American Society of Mechanical Engineers, the assembled engineers and guests were treated to a military parade and music provided by the drum and bugle corps of the Commonwealth Edison Post of the American Legion. Following an address of welcome given by H. B. Gear, chairman of the joint engineering societies' committee, the crowd was treated to a bit of effective drama in the form of the overhead manipulation of the autogiro and its subsequent landing on Soldiers Field just back of the speakers' stand. Following the presentation of the medal to Mr. de la Cierva and his brief response of appreciation, the ceremonial was brought to a close by the parade of a battalion of United States Infantry together with its military band. For an hour or so before its take off from Soldiers Field the autogiro was the center of attraction where it was the object of informal inspection by the attending crowds.

Participating in the Engineers' Day event

A New Diesel-Electric Generating Station



MODERNISTIC design features the new power house of the department of power and light, Vernon, Calif. Inside this station is an initial installation of 5 7,000-hp Hooven-Owens-Rentschler diesel engines driving 7,000-kva Allis-Chalmers 7,200-volt generators. The switching equipment is of the unit type metal-clad form supplied by the Delta-Star Electric Company. Provision in the station has been made for 5 additional generating units.

were: the American Society of Civil Engineers, the American Institute of Electrical Engineers, The American Society of Mechanical Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society for Testing Materials, the Society of Industrial Engineers, the Institute of Radio Engineers, the American Ceramic Society, the Society for the Promotion of Engineering Education, the National Council of State Boards of Engineering Examiners, the American Association of Engineers, the American Foundrymen's Association, the engineering section of the American Association for the Advancement of Science, the American Society of Refrigerating Engineers, and the Western (Chicago) Society of Engineers.

To aid the engineers in seeing as much as possible of the most interesting features of the World's Fair, the A.I.E.E. summer convention committee prepared a comprehensive itinerary and program, carefully worked out in detail and with full directions for finding one's way quickly from point to point through the maze of exhibits. The party assembled at 1:30 p.m. at the Thomas A. Edison memorial building and there broke up into informal groups. Guides for the groups were not provided but the profusion of well informed Exposition guides throughout the grounds and in all exhibit buildings were readily available whenever assistance was desired.

Closing the Engineers' Day program was the joint engineering societies banquet held under the auspices of the Western Society of Engineers, Chicago. This colorful affair was attended by many engineers and guests. Following an address of welcome by Hon. Edward J. Kelly, mayor of Chicago, there were 2 feature addresses: "Contribution of Engineering to Progress—A Review and Evaluation," by Edward J. Mehren, president of the Portland Cement Association, and "Science and Engineering," by Dr. Karl Taylor Compton, president, Massachusetts Institute of Technology.

Officers, Delegates, and Members Hold Annual Conference in Chicago

As a regular part of the summer convention activities, the conference of officers, delegates, and members of the Institute was held at Chicago, Ill., Monday and Tuesday afternoons, June 26 and 27, 1933, jointly under the auspices of the Sections committee and the committee on Student Branches. Present at these sessions were delegates from all Institute Sections, 3 of the 10 District secretaries, and counselor-delegates from 6 of the 9 Districts in which committees on student activities have been organized. In addition, of course, there were in attendance other officers, officers-elect, and members bringing the total attendance up to 108 persons. The principal topics discussed at the conference were, as outlined in a program previously mailed to the delegates and others:

Monday, June 26, 2:00 p.m.

1. Opening of conference:
Announcements by Everett S. Lee, chairman of the sections committee.
2. Remarks by President H. P. Charlesworth.
3. Remarks by President-Elect J. B. Whitehead.
4. Remarks by National Secretary H. H. Henline.
a. Report of action on recommendations made last year.
b. Report on action relative to report of membership committee.
5. Report of finance committee—C. E. Stephens.
6. Division into parallel sessions of Section and Student Branch delegates and members.

Session A—Section Meeting—Everett S. Lee, Chairman

7. Improving Section Activities
Experiences
a. Texas—B. D. Hull
b. Atlanta—O. O. Rae
c. New York—T. F. Barton
d. Schenectady-Pittsfield—V. M. Montsinger
e. Chicago—T. G. LeClair
f. San Francisco—W. C. Smith

Intermission

Discussion.

Session B—Student Branch and Enrolled Student Meeting—Prof. W. H. Timbie, Chairman

Tuesday, June 27, 2:00 p. m.

Session C—General—Everett S. Lee, Chairman

11. Discussion on improving Section activities (continued).
Discussion to be started by R. L. Kirk.
12. Section and Branch cooperation—Prof. W. H. Timbie.
13. Engineers' Council for Professional Development—L. W. W. Morrow.
14. Discussion.
15. The coming year—Dr. J. B. Whitehead.

For the opening and closing sessions of the conference the 2 groups met together, meeting the remainder of the time separately. Everett S. Lee, chairman of the Sections committee, presided over the joint meetings and the meeting of the Sections group; W. H. Timbie, chairman of the Student Branches committee, presided over the Student Branches group sessions. Since the annual report on Section and Branch activities had been published in full in the June 1933 issue of Electrical Engineering (p. 426–8), no pamphlet copies of the report were prepared for use at the meeting.

Opening Meeting

President Charlesworth in his few brief opening remarks reflected the impressions that he had gathered in his presidential visits to Institute Sections during the past year. He expressed himself as being very favorably impressed by the constructively aggressive policy being followed by most of the Sections visited.

Dr. J. B. Whitehead, in making a brief response to his formal induction as president-elect of the Institute, sounded an important thought concerning the relation between the Institute as a whole and its individual members. He emphatically expressed the point of view that the life and well being of the Institute rests with the Institute membership and that it is highly desirable that the individual member recognize his responsibilities and his actual place in the picture. He emphasized the importance of local Section activities, pointing out also the responsibility of the Section to initiate and carry on the work of the Institute. As his interpretation of the situation, he emphasized the necessity of recognizing that the Institute is not a central, beneficent, controlling organization, but rather a mutual, cooperative organization of individual members functioning in local Section units with activities coordinated through the central body.

National Secretary Henline reported on the present status of recommendations made at the 1932 conference in Cleveland. He reported also on the membership committee's report, mentioning the various committees of the Institute to which pertinent sections of that committee's report had been referred.

C. E. Stephens, chairman of the Institute's finance committee, sounded a note of optimism in reporting upon the state of the Institute's finances for the first 9 months of the current appropriation year. He was able to report that, for this period, total expenditures had been almost exactly offset by total revenue, a distinct improvement over the preceding year; that the outlook for the remainder of the appropriation year indicated that although total revenues for the year would be of the order of 10 per cent lower than estimated a year ago when the budget was made up, economies effected during the year would result in total expenditures lower than the budgeted expectancy by about the same percentage; that the originally budgeted $16,000 withdrawal from the reserve capital fund might not all be required to balance the budget for the current year. Mr. Stephens also was able to report that the reserve capital fund had appreciated some $17,000 in book value since March 4, 1933, totaling $123,397 as of June 22.

Section Meeting

The symposium of informal reports covering successful methods of improving Section activities was participated in by B. D. Hull, concerning the development of the Texas and Oklahoma City Sections; O. O. Rae, concerning the rejuvenation and reconstruction of the Atlanta Section; T. F. Barton, who outlined the salient features of the group activities of the New York Section; V. M. Montsinger, who described in some detail the effective competition among younger members that has stimulated the activities of the Schenectady and Pittsfield Sections; T. G. LeClair, who spoke of the promotion and educational activities of the Chicago Section; and W. C. Smith, who outlined the principal features of the San Francisco Section's organization plan which has operated with a high degree of success for the past 4 years. Following these presentations, active discussion ensued giving rise to an interchange of many useful ideas.

E. B. Meyer, chairman of the Institute's publication committee, outlined before the conference a plan of publication reorganization that has been studied by the committee for the past several months. In its essence, the proposed plan would provide for the consolidation of the present monthly ELECTRICAL ENGINEERING and the present quarterly TRANSACTIONS into one properly coordinated and unified publication to be issued monthly to all members of the Institute. After extended discussion, the following resolution was presented by Dr. W. B. Kouwenhoven:

RESOLVED, that the delegates approve the recommendations of the publication committee to publish the technical papers in ELECTRICAL ENGINEERING, and the other recommendations of that committee.

This resolution was adopted unanimously with the further recommendation that it be considered by the board of directors at its August meeting.

STUDENT BRANCHES MEETING

As a tangible result of their deliberations, the Student Branches group adopted 2 resolutions, bringing them before the joint conference group for confirmation:

RESOLVED, that it may be recommended to the board of directors that they adopt such changes in the by-laws of the Institute as will carry out the intent of the following recommendations:

1. That evening students in electrical engineering colleges be permitted to enroll as students of the Institute for a period of not more than 5 years;

2. That the evening students in electrical engineering be permitted to organize with their own officers.

RESOLVED, that it may be recommended to the board of directors that in each future annual budget, sufficient funds be allocated to insure the continuance of the annual District Student activity conferences, and that the travel allowances to such meetings in any one year, for one student chairman and one counselor from each Branch, be made at the same rate as may be in force for the Section delegates and others to whom travel allowances are granted.

The first resolution was presented before the reconvened joint session by Prof. W. H. Timbie; the second was presented by Prof. W. S. Rodman of the University of Virginia, University, Va. Both resolutions were adopted by unanimous vote.

GENERAL MEETING

Other activities at the second afternoon's session included an informal and general discussion and exchange of ideas concerning various Section problems, a review of the present status of activities of the Engineers' Council for Professional Development presented by L. W. W. Morrow, newly elected member of the board of directors, and a brief talk by President-Elect J. B. Whitehead.

Concerning the Engineers' Council for Professional Development, Mr. Morrow outlined the ambitious scope of its intended activities which, in brief, includes suitable guidance for engineering students and graduates from the high school period through the college and apprenticeship or pre-professional period, embracing groups ranging in age from approximately 16 to approximately 30 years. He said in part "Men have looked around at the legal profession and at the medical profession, and have seen, either through legislation or some other traditional procedure, the development of a professional standing that is high. . . . In contrast to that, we have engineers of many categories. . . .and various engineering groups growing up with new names for engineering societies." The organization of the council and its work was reported as progressing steadily; committees on student selection and guidance, engineering schools, professional training, and professional recognition were reported as already appointed. The programmed activities were reported to include:

1. The development of further means for educational and vocational orientation of young men with respect to responsibilities and opportunities of engineers, in order that only those having the quality, aptitude, and capacity required of members of professional societies may seek entrance to the profession.

2. The formulation of criterions for colleges of engineering that will insure to their graduates a sound educational foundation for the practice of engineering.

3. The development of plans for the further personal and professional development of young engineering graduates, and also those without formal scholastic training.

4. The development of methods whereby engineers who have met suitable standards may receive corresponding professional recognition.

Doctor Whitehead, although the subject assigned to him was "The Coming Year" declined to offer any forecast. He did, however, reemphasize his previously stated belief that the welfare of the Institute and the successful development of its activities is a responsibility that rests entirely on the membership, individually and acting through the Section groups. He pledged his best efforts to promote, as president, the welfare of the Institute.

The general tone of the conference was spoken of by many of those in attendance as being the most inspiring and constructive of such conferences held during recent years. Some expressed the belief that more time should be allotted to these sessions and time made available for the convenience of small discussion groups.

A.I.E.E. Directors Meet During Chicago Convention

The regular meeting of the board of directors of the American Institute of Electrical Engineers was held at the Stevens Hotel, Chicago, Ill., June 28, 1933.

Present were: *President*—H. P. Charlesworth, New York, N. Y. *Past-president*—W. S. Lee, Charlotte, N. C. *Vice-presidents*—K. A. Auty, Chicago, Ill.; L. B. Chubbuck, Hamilton, Ont.; A. W. Copley, San Francisco, Calif.; W. E. Freeman, Lexington, Ky.; C. R. Higson, Salt Lake City, Utah; J. Allen Johnson, Buffalo, N. Y.; W. B. Kouwenhoven, Baltimore, Md.; E. B. Meyer, Newark, N. J.; P. H. Patton, Omaha, Neb.; Stanley Stokes, St. Louis, Mo. *Directors*—L. W. Chubb, East Pittsburgh, Pa.; A. B. Cooper, Toronto, Ont.; B. D. Hull, Dallas, Tex.; A. E. Knowlton, New York, N. Y.; G. A. Kositzky, Cleveland, Ohio; A. H. Lovell, Ann Arbor, Mich.; F. W. Peek, Jr., Pittsfield, Mass.; C. E. Stephens, New York, N. Y.; A. C. Stevens, Schenectady, N. Y. *National treasurer*—W. I. Slichter, New York, N. Y. *National secretary*—H. H. Henline, New York, N. Y.

Present by invitation were: *Past-presidents*—Dugald C. Jackson and A. E. Kennelly, Cambridge, Mass. *Officers-elect*—J. B. Whitehead, Baltimore, Md.; F. M. Craft, Atlanta, Ga.; Everett S. Lee, Schenectady, N. Y.; R. W. Sorensen, Los Angeles, Calif. *Chairman, technical program committee*—W. H. Harrison, Philadelphia, Pa.

The minutes of the board of directors' meeting of May 22, 1933, were approved.

A report was presented and approved of a meeting of the board of examiners held June 21, 1933. Upon the recommendation of the board of examiners, the following actions were taken upon pending applications: 6 applicants were transferred to the grade of Fellow; 6 applicants were elected and 19 were transferred to the grade of Member; 52 applicants were elected to the grade of Associate; 107 Students were enrolled.

The chairman of the finance committee reported disbursements in June amounting to $15,289.83.

Decision was made, upon the recommedation of the committee on coordination of Institute activities, to hold the 1934 summer convention at the Homestead Hotel, Hot Springs, Va.

Amendments to the Institute by-laws were adopted as follows, in order to conform with a statement of policy regarding non-member authors which was approved by the board of directors at its May meeting:

Sec. 35 (pertaining to District meetings)—Second sentence of second paragraph changed to read as follows:

"This committee shall have full responsibility and authority for organizing and conducting such meeting in all its details, including the arrangement of sessions, the entertainment features, and, subject to Section 91 of the by-laws, the selection of papers."

Sec. 45 (relating to Section and Branch papers)—The following sentence added:

"Where publication in TRANSACTIONS of Section or Branch papers by non-members of the Institute is involved, approvals shall be obtained in accordance with Section 91 of the by-laws."

Sec. 91—The following new by-law substituted for the old Section 91:

"Sec. 91. All committees responsible for the preparation of technical programs shall so direct their activities that all authors of technical papers will be members of the Institute in so far as this is consistent with keeping the membership fully informed as to developments in the electrical arts and sciences and in closely allied fields. It is recognized that there may from time to time be situations in which non-member authors or co-authors are desirable in order to obtain an authoritative presentation of the subject matter, particularly in fields foreign but closely allied to the electrical arts and sciences. In such cases, papers by non-members may be accepted under regulations approved by the board of directors."

Dr. Dugald C. Jackson was appointed a representative of the Institute upon the division of engineering and industrial research of the National Research Council, for the 3-year term beginning July 1, 1933.

President Charlesworth presented his resignation as a representative of the Institute upon the assembly of American Engineering Council, effective July 31, 1933, and Dr. J. B. Whitehead, the president-elect, was appointed to succeed Mr. Charlesworth.

Resolutions of appreciation of the effective services of the general summer convention committee and its subcommittees, and of the women's entertainment committee, were adopted; and appreciation of the cooperation and courtesies extended by the management of the Edgewater Beach Hotel to the members and guests in attendance at the convention was expressed.

Other matters were discussed, reference to which may be found in this or future issues of ELECTRICAL ENGINEERING.

Summarized Review of Some Summer Convention Discussions

PRINCIPAL discussions of the summer convention papers are summarized herewith. The papers to which these discussions refer were abstracted in ELECTRICAL ENGINEERING for June 1933, p. 412–9, excepting the papers given more complete treatment in that issue. Additional articles based upon these papers are being presented in subsequent issues.

Only discussion submitted in writing in accordance with governing A.I.E.E. rules is summarized. Complete discussion, together with all approved papers, will be published in the TRANSACTIONS.

Protective Devices

TESTING OF HIGH SPEED DISTANCE RELAYS

R. C. Buell (Schenectady, N. Y.) in his discussion of this subject advocated the use of an automatic oscillograph as the only accurate method available to obtain information actually to check relay operation during system disturbances. It was his belief that staged tests were expensive and that the elimination of the necessity for just one test would justify the use of an automatic oscillograph which would be available constantly to check the proper operation of relay equipment.

H. R. Huntley (New York, N. Y.) as a telephone man, expressed his appreciation to the author for brining out so clearly the need for and advantages of cooperation with the communication organizations in cases where ground faults are to be placed on power transmission lines in connection with relay testing.

M. S. Schneider (Cincinnati, Ohio) in a part of his discussion of this subject placed special emphasis on the wave form of current and voltage when testing any relays with low voltage and in particular distance relays. Wave form might have considerable effect on calibrations. It was not believed sufficient that the impressed voltage be sinusoidal as the iron present in relay circuits will usually distort considerably the current wave unless precautions are taken. This distorted current he believed, might have considerable effect not only on the relay but also on the indicating instruments.

A. R. van C. Warrington (Philadelphia, Pa.) in his discussion of this subject emphasized the value of initial system tests, which he believed gave the surest method of setting distance relays since they check the overall characteristics of the line, current transformers, potential transformers, and relays. The discusser congratulated the author for his enterprise and wisdom in making system tests a part of his system routine.

RELAYING OF HIGH VOLTAGE INTERCONNECTIONS

H. D. Braley (New York, N. Y.) discussed the part that system stability has taken in the protective field. In regard to the use of distance relays in combinations with carrier current control, he believed it doubtful that this would ever offer a complete solution. He explained that any distance relay which is located at or near the reactance center of the system may be subject to low or actually zero voltage during severe surging or out of step conditions. As system connections are changed due to lines being out of service or changes in connected generating capacity the reactance center, or electrical neutral, will also shift. Therefore under some conditions the lines may be tripped out at one point and for other conditions at another point. For these reasons the discusser offered an amendment to the fourth item of the "requirements of the ideal relay scheme" to the effect that in case the systems lose synchronism the relays should operate to effect the separation at a preferred point only.

L. N. Crichton (Newark, N. J.) considered the economics of the proposed scheme. He pointed out that if the system is not always operating under full conditions instability will result due to sequential operation. But even if a perfect relay system is provided there are sure to be some failures of service. There is the occasional catastrophe, and there is the more frequent trouble in some lightning districts where more than one section of line is grounded either by the same lightning stroke or by several strokes separated by a short interval of time. If this occurs in such a way that all the ties are interrupted, the systems will be separated. Therefore, possibly on many systems the expenditure for the carrier current to provide the additional last fraction of protection may not give sufficient return to justify itself. If absolutely continuous service could be secured it might be justified but, if total yearly failures were reduced from, say 2 interruptions to say 1 of the unavoidable ones, in his opinion, it might not be considered justifiable.

E. E. George (Chattanooga, Tenn.) in his discussion of this paper cited the operating as well as economic advantages of distance relays. He also cited a new factor in favor of pilot wire relaying in the way of reduced rates by the communication companies for this class of service. He believed that, if rates for leased pilot wire service were lowered sufficiently and maintenance practices were modified to suit the power companies, probably no other scheme of protection now known could hope to compete with the pilot wire for transmission line protection.

O. C. Traver (Philadelphia, Pa.) predicted that all of the author's difficult requirements will, in time, be met excepting possibly the one of cost. Usually, cost will follow the general rule of varying with value and this will be inversely as the reduction in time. He explained that this tendency toward increase will, on the other hand, be tempered as usual by the effects of quantities and experience.

E. M. Hunter and E. H. Bancker (Schenectady, N. Y.) in their discussion commented upon and contrasted several schemes of relay protection. They felt it was noteworthy that attention is turning once more to one of the oldest and most nearly ideal forms of relaying, namely, pilot protection. It was the opinion of the discussers that, when all of the factors are taken into consideration, some form of pilot relaying could be economically justified on practically every important interconnection between large systems. This is especially true of systems operating near the stability limit, since pilot relaying is more easily rendered insensitive or immune to oscillations than any type of distance relay.

Another discusser, E. Ettlinger (Chicago, Ill.) referred to the satisfactory results obtained with a pilot wire relaying scheme employing Bell System lines which he had recently reviewed. An indicating type of instrument was used to give the condition of the leased wire circuit continuously and, although some discontinuities had occurred, they did not interfere with power line relaying. In his opinion rates for leased wire services were sufficiently low so that specific study of situations is warranted to determine the economies of pilot wire relaying *versus* carried current pilot relaying.

S. L. Goldsborough (Newark, N. J.) discussed the idea of compelling a distance relay to continue to indicate according to its original interpretation. He explained that this idea was entirely feasible and it could be carried to considerable advantage in some cases.

INTERRUPTING CAPACITY TESTS ON CIRCUIT BREAKERS

W. D. Ketchum (Birmingham, Ala.) considered the influence of the decrement of the short-circuit current upon circuit breakers performance on OCO tests. He pointed out that when a multi-shot cycle is made, with a substantial decrement, the effect upon the circuit breaker might be much more severe than in the case of the same number of CO shots. This, he explained, was particularly true for heavy current values such as exist when the test is made at lower than rated voltage. It was suggested that uniform decrement conditions approximating field conditions should be maintained whenever possible in testing.

W. F. Sims (Chicago, Ill.) in his discussion of this subject gave several very logical reasons why factory tests are preferable to field tests. The discusser also explained that it is essential to test the closing ability of breakers on short circuits in order to determine the presence of unexpected magnetic, frictional, and hydraulic forces.

A Compression Type Low Voltage Air Circuit Breaker

J. B. MacNeill (E. Pittsburgh, Pa.) in his discussion of this subject, explained that he was not in agreement with the author's statement that this is a new device operating under a new theory. It was not believed to be new in principle as a patent covering a construction very similar to the one used by the author was issued to the discusser in 1926, and the same principle was incorporated in a line of circuit breakers designed in 1929. About that time means were found of introducing effective deionization through plate structures in small capacity units. These plate structures offer more promise of eliminating the difficulties countered. Experience with the compression type showed that the idea of mounting the main contacts completely enclosed in the compression chamber gave rise to maintenance problems and that the action on low power factor arcs and inductive d-c arcs was not ideal.

H. R. Summerhayes (Schenectady, N. Y.) advocated for study by the distribution engineers the use of these circuit breakers on the secondaries of each transformer so that transformers could be banked on the strictly radial systems. The thermal tripping arrangement of the breaker could be adapted to the thermal overload capacity of the transformer to give sufficiently selective action without the disadvantages attending the use of secondary fuses.

J. Slepian (E. Pittsburgh, Pa.) discussed the theory of the extinction of the arc in the compression chamber, particularly the d-c arc. In regard to the explanation that increasing the pressure of the gas sufficiently will certainly raise the arc voltage, he cited that other investigators did not record as much of an effect as indicated in Fig. 2 of the paper. The discusser did not believe that this was the whole story as regards the extinction of the arc in this breaker, and he analyzed the results presented by the author. This led to the raising of a number of pertinent questions in regard to the theory of performance.

Installation and Performance of High Voltage Lightning Arresters

Herman Halperin (Chicago, Ill.) cited their experiences with over 33,000 arresters on 4-kv distribution systems. Most of the failures could be assigned to mechanical weakness. It was explained that the moisture entrance not only leads to complete failure but it also is a primary cause of corrosion which permits leakage to ground with resulting radio interference troubles. Contrary to part of conclusion 7 in the paper and all of conclusion 8 their data indicated that modern 3-kv arresters were less susceptible to damage than old arresters and also that they afforded better protection to transformers.

H. A. P. Langstaff (Pittsburgh, Pa.) stated that their experience with arresters in recent years indicated conclusively that moisture is causing a higher percentage of arrester failures than on other equipment. It was suggested that manufacturers should include in routine tests an arrangement whereby designs would be subjected to conditions the equivalent of several years of actual service. The discusser was also of the belief that the internal parts of arresters should be non-corrosive and of such material that the formation of fungus would be impossible. Several recent interesting protective applications were also described by the discusser.

Another discusser, K. B. McEachron (Pittsfield, Mass.) drew attention to the extreme importance of service experience. In reference to conclusion 8 in the paper that practically all apparatus failures had occurred on equipment protected by the older types of lightning arresters, he offered the following possible explanations. Part of the lack of protection might have been due to the condition of the older apparatus which, of course, the questionnaire made no attempt to evaluate. At the same time not only have improvements been made in arresters, but those installed in recent years have in general been in a more favorable position to do efficient work, particularly on account of a better understanding of the importance of installation details, such as location grounds, etc.

Instruments and Measurements

Compensating Metering in Theory and Practice

A. Boyajian (Pittsfield, Mass.) cited a number of reasons that would limit the field of application for this scheme. Among these limitations he pointed out that 3-winding and 4-winding transformers would complicate the scheme to such an extent as to greatly reduce or eliminate its economy; also tap changing, especially if automatic, would make the loss measurements of doubtful approximation. In addition, 20 per cent difference between the hot and cold impedance losses and the wide variety of core loss exponents with voltage in different transformers might become an appreciable item in some cases, such as when power flows in both directions, as in an interconnection. He also cited that other low voltage metering schemes of even greater economy and accuracy than the one proposed have found but very limited use, and in conclusion he was of the opinion that none of these schemes from the standpoint of engineering accuracy could compare with the modern high voltage instrument transformers.

Another discusser, Stanley Green (Lafayette, Ind.) held the opposite contention. It was his belief that compensating metering was of interest because it has possibilities for making a measurement which fundamentally the watthour meter with its instrument transformers is not able to accomplish adequately. He referred to the accuracy of the best modern watthour meters below 5 per cent of full load current and at extremely low power factors. He explained that results obtained in this region would change, not only because of unavoidable variations in friction but because of inherent design characteristics that vary in different types of meters. In conclusion, he cited that an inherent advantage of the method from a statistical standpoint was the ability to segregate the actual transformer losses from the useful energy, thereby calling attention to undesirable conditions if they should exist.

Paul MacGahan (Newark, N. J.) in his discussion of this subject, pointed out, as a matter of record, that the method in the paper is not new and he cited references to previous treatments of the subject. As to why there has been no demand in America for the application of this system of metering, in the discusser's opinion, this may have been due to the difficulty in determining the proper calibration to suit each separate installation and also in proving the correctness of the result.

Better Instrument Springs

In another discussion, Paul MacGahan (Newark, N. J.) gave an interesting account of the early developments some of which were determined purely by experiment. He then pointed out wherein some of these early developments were verified later by rational point of view from the results obtained in this paper. He explained that in the early days the effects of temperature, frequency, and friction entirely obscured the smaller spring errors. As the electrical and mechanical features of the art progressed, it was realized that an instrument could be no more accurate than its control spring. It should not be assumed that spring practice in those days was all wrong but rather that the performance required of modern instruments calls for a better knowledge of spring defects. He pointed out that in the early precision instruments with over 300 deg deflections, and many of which are still in use, a spring error of $^1/_{60}$ of 1 per cent would be discovered if it were present. This excellent performance was attributed to the fact that the springs were then much larger in size and not as thinly rolled as those in common use today. One of the interesting points which the discusser tied in with the presence of residual stresses, as disclosed in the paper, was in relation to William Bradshaw's curve of the characteristic deviation of the precision meter spring published in 1906. He suggested as a rational view of this long-known peculiarity in the deflection rate of springs that the deviation might be explained as arising from the combination of load stresses and residual stresses.

A Portable Oscillograph With Unique Features

In connection with this subject, E. S. Lee (Schenectady, N. Y.) reviewed the developments of the oscillograph from the time of Blondel's early design in 1891. In 1904 the company with which he is associated produced its first electromagnetic oscillograph. For years this was quite generally used until the advent a few years ago of the permanent magnet galvanometer oscillographs. He referred to the portable 2-element oscillograph described by his associates before the Institute May 7, 1930. This oscillograph extended the photography range to include the photography of transients, and it was the discusser's understanding that the design described in the present paper by Mr. Oplinger did not do this. The discusser also referred to the pioneering work of du Four in the important field of cathode ray oscillographs. Lantern slides showed an installation of this type of oscillograph in the mountains of Pennsylvania, where the first wave form of a lightning surge on a transmission line to be photographed in the United States was obtained. A sealed evacuated tube for low voltage work has dispensed with need of the vacuum pumps, and he predicted that this feature would some day be extended to the higher voltage range for general purpose impulse testing. The advent of the photoelectric recorder, which dispensed with point-by-point plotting of wave forms by hand, also was related. In conclusion, he paid tribute to the outstanding contributions to oscillography by the late Dr. L. T. Robinson and the late Mr. J. W. Legg.

Power Transmission and Distribution

THE EXPULSION PROTECTIVE GAP

L. V. Bewley (Pittsfield, Mass.) discussed the effect of tower footing resistance on the operation of the expulsion protective gap. It was explained that these gaps have an upper and lower limit, in the present designs the span of these limits being from about 4:1 to 10:1. Essential considerations for the selection of gaps for a given system were set forth. He also explained that in the neighborhood of the station it is advisable to reduce the tower footing resistances to very low values—of the order of a few ohms—for by so doing the duty on the station protective devices will be minimized.

V. M. Montsinger (Pittsfield, Mass.) discussed expulsion gaps in the interest of preventing someone who might not realize their limitations from attempting to use them in establishing coordination of station apparatus. It should be remembered that the expulsion protective gap is intended for the protection of line insulation against outages and not as a protective device to station apparatus. In conclusion, he stated that the expulsion gap cannot be used either as a protective device to station apparatus or as a regular coordination gap.

A. M. Opsahl (E. Pittsburgh, Pa.) in his discussion of this subject stated that he was very glad to see the authors have decided to use methods of design such that standardization in this field will occur early in the development. He was of the belief that there was an inconsistency in the table of insulation which the authors state the units will protect. He pointed out that on positive surges the 35-in. rod gap is equivalent to about 6 of the suspension insulators or, if 7 of the suspension insulators are required, he believed it would be necessary to have approximately a 43-in. rod gap to give equivalent flashover.

A discussion of this subject by Philip Sporn (New York, N. Y.) was presented by L. L. Perry. It described an experimental installation of 132-kv expulsion protective gaps on one circuit of the 65-mile Glenlyn-Roanoke line. The discussion related the construction problems encountered in applying these gaps to all 3 phases of a circuit with an effort to keep the tower structure clear and open for purposes of line inspection, maintenance, and repair. Three methods of gap mounting are being used: first, the single angle mounting of the gap on the structure; second, the mounting of the gap on the nsulator assembly; and third, a modification of the second method where the gap is mounted in 2 parts on the insulator assembly. All 3 methods of mounting are being used to determine from the very start the relative advantages and disadvantages of the different types of mounting from actual operating experience. The discusser believed that successful operation of the expulsion protective gap in actual service over a period of time would be a distinct step forward in applying practical lightning protection to high voltage lines. The operation of this installation will be carefully watched, not only from the point of view of performance and protecting the line against lightning flashover and interrupting power current but also its ability to withstand weather, the elements, and the best method of mounting.

L. L. Perry (Chicago, Ill.) in his discussion pointed out that lightning in some localities is a much greater hazard than in others. Hence, when these devices are installed in a territory where lightning conditions are severe they may prove to be decidedly economical, whereas, when they are installed elsewhere, such as on the western mountain slopes of California, they may prove to be extravagant and hazardous.

Another discusser, H. S. Phelps (Philadelphia, Pa.) considered the limitations cited in the paper to be especially important when installations are contemplated on systems where different switching set-ups permit supplying energy to a given point from different sources or even the same source but over different routes. He pointed out that under such conditions the short-circuit kilovoltamperes for a given set-up may exceed the capacity of the expulsion tubes, while for a different set-up the short-circuit kilovoltamperes may be adequate for proper functioning of the protective device.

THE DEION FLASHOVER PROTECTOR AND ITS APPLICATION TO LINES

R. E. Hellmund (E. Pittsburgh, Pa.) in his discussion of this subject related that the significance of the availability of such inexpensive devices as described in the paper, together with the more general application of surge-protected distribution transformers, is that all exposed parts of the system now can be economically protected against surges. He also referred to the limitations of application in that it is applicable only for line protection and normally designed station equipment must still be protected by suitable lightning arresters.

H. S. Phelps (Philadelphia, Pa.) believed that the discussion in the paper of the situation that exists upon interruption of power current by 1 of 2 protectors connected to a common ground, that have functioned simultaneously, emphasized the care that must be exercised when selecting protectors for low voltage lines capable of delivering high values of fault current. The discusser hoped that when more operating experience has been acquired that the authors will make this information available.

Another discusser, J. Slepian (E. Pittsburgh, Pa.), told about the origin of the deion flashover protector. This, he attrib-

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Cutting Timber in the Pacific Northwest

Westinghouse Photo

USE of electric power in the lumber industry of the Pacific Northwest has increased greatly in the past 2 decades. It has been estimated that those industries of the Pacific Northwest which use forest wood as a raw material have an annual electric energy consumption of more than 2 billion kilowatthours. Shown here is an electric logging donkey and loader, one of the many types of equipment contributing to this extensive use of electric power.

uted to the alertness of Mr. Torok in recognizing how the special properties of insulator strings and transmission lines and the then newly discovered facts and theory of the extinction of a-c arcs in self-generated gas blasts would fit together one with the other to permit the development of a new kind of protection against outages by lightning. He also described how the special properties of the protective and protecting device cooperate to give the extremely simple and practical deion flashover protector.

The Life of Impregnated Paper

Herman Halperin (Chicago, Ill.) discussed the statement in the paper that the penetrative power of oil to the life of the impregnated paper insulation increases with the square root of the effective capillary radius of the paper. From this, he believed, it might be concluded that the life of impregnated paper insulation in cables would be higher with low density paper than with the high density paper. On the other hand he pointed out that in recent years there has been a tendency to use high density paper, particularly adjacent to the conductor. The discusser's limited data on short and long time high voltage tests also indicated that the unit breakdown strength is slightly increased by the use of the higher density paper.

D. W. Roper (Chicago, Ill.) in his discussion of this subject cited commercial considerations which indicated the desirability of continuing the studies on the solid type of insulation. He also pointed out that, in order to get the benefit of the higher permissible operating temperature of oil filled cable, either the cable must be installed in separate conduits, or other cables in the same conduit must be de-rated to prevent their maximum temperature from exceeding safe limits.

Another discusser, K. S. Wyatt (Detroit Mich.), said that this paper is an excellent piece of work in an exceedingly difficult field, namely breakdown. He complimented the author on his success in sufficiently controlling the many variables so as to bring order out of chaos and establish a definite relationship. The dependency of life upon the penetrativity of the compound, together with the method for determining penetrativity, was believed to constitute a valuable contribution which cannot help but influence practice.

R. J. Wiseman (Passaic, N. J.) in his discussion drew attention to the fact that these tests were made under ideal control conditions which must be so, to classify oils properly. However, the final answer would not come until cable has been made up and accelerated aging tests are conducted, such as Mr. Roper has done or some other way, in order to introduce all influencing factors.

Accelerated Aging Tests on High Voltage Cable

H. A. Dambly (Philadelphia, Pa.) presented operating data which showed the record of failures attributed to insulation defects or deterioration for 3 66-kv installations. This data supported the view expressed in the paper in regard to the importance of loading. On 2 of the heavily loaded installations 9 failures occurred in 1932 that were attributed to insulation deterioration, while on the lightly loaded installation no failures attributed to insulation defects had occurred since January 1928.

C. L. Dawes (Cambridge, Mass.) described some of the results obtained from accelerated life tests on 10 different samples from 6 different manufacturers. He stated that a number of the results and conclusions from the accelerated life tests of cables given in the paper are in accord with some of those obtained at the Harvard Engineering School.

W. F. Davidson (Brooklyn, N. Y.) believed that the method of accelerated aging tests seemed to be particularly effective and he expressed hope that further work will be done along the same line with cables of other types. He felt that the results so far obtained are very helpful in evaluating the effectiveness on acceptance tests of new cable. They also appeared to be helpful as a type test in connection with the rating of cable of new designs for construction.

W. A. Del Mar (Yonkers, N. Y.) pointed out that this paper, by clearly showing the superiority of high voltage cables having low ionization, both in service and in load cycle life tests, indicates that cables which are practically gas free behave better than those with a little residual gas. He explained that this is a very significant discovery and contrary to the general belief of a few years ago. The discusser offered the following explanation of the comparative innocuousness of vacuous ionization. Air films are permanent in relation to the paper and merely expand and contract in the load cycle. Vacuums are not permanent but appear, disappear, and reappear in different places, each load cycle. The ionization in air films, therefore, produces accumulative deterioration of the paper, while ionization in vacuums is non-accumulative and, therefore, comparatively harmless.

Another discussion by R. J. Wiseman (Passaic, N. J.) drew attention to the improvement in quality of 66-kv cables in recent years. The discusser believed that the author would have obtained even better results if he had used cables of a later vintage than 1926. The discusser also seriously considered the lead sheath problem which has been brought about by a reduction in voids and high internal pressures. He emphasized the recommendation to increase the thickness of lead sheaths for the larger diameter cables.

A New Method of Investigating Cable Deterioration

W. A. Del Mar (Yonkers, N. Y.) complimented the authors for the completeness with which they have prepared a valuable research tool for use. He felt, however, that the paper stopped short of any important application of this tool and he expressed hope that the authors would proceed with applications to the problems of dielectric failure. To indicate how this new tool might be used for researches into the origin of insulation failure, the discusser considered the authors' statement that the radial hydrophil curve does not always completely explain the radial power factor curve. The power factor curve of Fig. 12 was particularly interesting to the discusser because it corresponded in a general way with the occurrence of dendrites in a single conductor cable with thick insulation. He explained that dendrites originate as a rule about 1/3 of the way radially from the conductor surface, the very place where Fig. 12 shows the power factor to be a maximum. The discusser applied several theories which have been proposed to account for this.

R. L. Dodd (Milwaukee, Wis.) considered the prevention of air from entering the cable at the time of installation. He explained that a device for puncturing the sheaths under oil and reimpregnation in the field has been in use on 27,600-volt cables in Milwaukee since early in 1931. Each cable end is treated with suitable cable oil to refusal at a pressure of 15 lb per sq in. above atmospheric pressure. Some cable ends will admit no oil, while others take as much as 5 lb before refusal. The average amount admitted under this treatment varies from about 1/4 lb in summer to 1 lb in winter. The average time required is less than 10 min.

J. B. Whitehead (Baltimore, Md.) discussed this paper and raised 2 questions as regards the power factor-hydrophil relations. First, why should the hydrophil content in the center of the laboratory aged cable of Fig. 6 be so much lower than that of the new cable? Second, what is the relation of the values of power factor as measured on the individual tapes to the over-all power factor of the cable? He commented to the effect that the results in the paper indicate in a very definite manner that there are 2 and perhaps more types of deterioration in cables. That due to ionization, the common result of which is wax formation, has long been recognized. The second type, namely, an increase of power factor due to hydrophil content, is new. It is, therefore, important to examine as well as possible its probable importance. Some of the values of power factor due to this cause are apparently very high and so constitute serious limitations or danger. On the other hand the discusser pointed out that these values pertain to the tapes, alone, and it is not stated what is the over-all power factor of the cable,

C. F. Harding (Lafayette, Ind.) discussed this group of cable papers. It seemed to him unfortunate that more emphasis had not been placed upon impulse tests of the complete cable, both new and deteriorated by usage, and of the constituent parts of the cable, respectively. He explained that recent researches have confirmed the theory that surges of considerable magnitude may enter such cables and superimpose their steep-front transient potentials upon the low-frequency potentials in such a time sequence as seriously to stress the dielectric therein. He suggested that it would seem to be advisable to undertake further research with the use of impulse generators so synchronized that the 60-cycle supply has to provide in the laboratory these various time sequences of exposure for new and deteriorated cable and for the constituents of such cables.

Editor's Note: The remainder of these summaries of summer convention discussions is scheduled for inclusion in the September 1933 issue of ELECTRICAL ENGINEERING.

1933 Lamme Medal Nominations Due Nov. 1

In fulfilment of by-law requirements, a second posting is hereby given to the necessity of all nominations for the Lamme Medal for 1933 being submitted not later than November 1, 1933. (See ELECTRICAL ENGINEERING, June 1933, p. 421.) Presentation of the 1932 Lamme Medal was made to Edward Weston (A'84, M'84, Member for Life and past-president) chairman of the board, Weston Electrical Instrument Corp., Newark, N. J., at the opening session of the Institute's recent summer convention at Chicago, Ill.

San Francisco Section Increases Its Membership.—Due principally to the well planned technical programs of that Section, an increase in Institute membership of 12 per cent in the San Francisco, Calif., Section is reported for the fiscal year ending April 30, 1933. This gain in membership during these trying times gives an indication of the spirit of the electrical engineers in that area. Splendid work has been done by both the program and arrangements committees, and this is verified by the increasingly large attendance which is reported for the meetings.

A.S.M.E. Nominates Officers.—Nominations for officers of the American Society of Mechanical Engineers for 1934 were announced at a recent meeting of the nominating committee held at Chicago, Ill., during the semi-annual meeting. Election will be held by letter ballot of the entire membership, closing on September 26, 1933. The nominees as presented by the regular nominating committee of the society are: *President*—Paul Doty (A'04, M'12) chairman of the board, Minnesota State Board of Registration, St. Paul, Minn. *Vice-presidents*—H. L. Doolittle, designing engineer, Southern California Edison Company, Los Angeles, Calif.; W. L. Batt, president SKF Industries, Inc., New York, N. Y.; E. C. Hutchinson, president, Edge Moor Iron Company, Edge Moor, Delaware; E. H. Whitlock, Cleveland, Ohio (formerly research professor, mechanical engineering, Stevens Inst. of Tech., Hoboken, N. J.); *Managers*—J. M. Todd, Consulting Engineer, New Orleans, La.; E. L. Ohle, professor mechanical engineering, Washington University, St. Louis, Mo.; J. A. Hall, professor mechanical engineering, Brown University, Providence, R. I.

American Society for Testing Materials Elects Officers.—At the annual meeting of the American Society for Testing Materials held in Chicago, Ill., June 26, 1933, announcement was made of the election of officers of the society for the year 1933–34. President of the society is T. R. Lawson, head, department of civil engineering, Rensselaer Polytechnic Institute, Troy, N. Y.; as vice-president is Hermann von Schrenk, consulting timber engineer, St. Louis, Mo. The president's term is one year and the vice-president's 2 years. As members of the executive committee, the following were elected: F. A. Barbour, consulting hydraulic and sanitary engineer, Boston, Mass.; A. C. Fieldner, chief engineer, experiment stations division, U.S. Bureau of Mines, Washington, D. C.; C. N. Forrest, representative, the Barber Asphalt Co., Philadelphia, Pa.; J. C. Pearson, director of research, Lehigh Portland Cement Co., Allentown, Pa.; and A. E. White, professor of metallurgical engineering, and director, department of engineering research, University of Michigan, Ann Arbor.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or to reject them entirely.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

Production of Soft X Rays

To the Editor:

Concerning the letter suggesting a combination of X rays published in the July 1933 issue of ELECTRICAL ENGINEERING, p. 510, I wish to offer the following answer.

Sound is considered as a series of longitudinal waves passing through the air. A longitudinal wave is one in which the particles are displaced in the direction of the line of propagation. This displacement causes a series of condensations and rarefactions of the particles of the air whereas before displacement the particles were equidistant. These conditions are given in Fig. 1, showing the positions of the undisplaced particles, and the instantaneous relative positions of the displaced particles.

These condensations and rarefactions are carried along through the air with a velocity that of the sound. This is so because the particles all have the same amplitude of vibration about their initial position except for the slight diminution causing the sound to finally fade away entirely, but have different phases of vibration. This is somewhat analogous to the propagation of a sine wave along a line. Such rarefactions and condensations due to 2 waves may be added algebraically giving rise to what are called beats, which have a frequency equal to the difference of the frequencies of the 2 waves. In Fig. 1 *R* represents the instantaneous rarefaction, *C* the instantaneous condensation, and *N* the instantaneous normal condition.

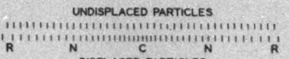

Fig. 1

On the other hand, however, electromagnetic waves, of which X rays are a type, are transverse waves and do not possess this property of combining to form what are called beat notes in sound. Combining 2 electromagnetic waves will result in no frequencies which were not present in the original waves combined. This may be readily verified by combining 2 monochromatic light beams of different frequencies and resolving the combination by a spectrograph. Furthermore, A. L. Hughes and G. E. M. Jauncey report negative results from an experimental attempt to show the collision of photons to produce photons of new frequencies (see "An Attempt to Detect Collisions of Photons, *Phys. Rev.*, v. 36, 1930, p. 773–7). Since light and X rays are both electromagnetic waves differing only in their wave lengths, the X rays having a much shorter wave length than visible light, it seems improbable that 2 streams of X rays of different frequencies can be combined in such a way as to produce softer X rays, that is, X rays of lower frequencies. Consequently success lies undoubtedly in another method of bringing the soft X rays to the point desired.

Yours very truly,

KERMIT F. R. RIEDY (A'33)
(Graduate Scholar, Physics Department, Pennsylvania State College, State College, Pa.)

The Engineering Economist of the Future

To the Editor:

In discussing Dean Kimball's paper which he presented at a joint meeting of the Econometric Society, The American Society of Mechanical Engineers, the American Society for Testing Materials, and the A.I.E.E., held in Chicago, Ill., June 30, 1933, I shall address myself to several aspects of the subject that he treats so ably. [ED. NOTE: Full text of Dean Kimball's paper appears elsewhere in this issue.]

First, in recent years there has been in some quarters a feeling that the engineer, now flushed with the glory of his recent achievements can and should step into the field of economics and solve, out of hand, problems that for generations have vexed some of the best brains in the world. I agree with Dean Kimball in believing that those who entertain such ideas are placing altogether too high an estimate on the abilities of engineers. I feel also that the childlike enthusiasm with which they advocate such simple and hasty entrance into a new sphere of activity demonstrates clearly so small an appreciation of the characteristics of that sphere that for the time being at least they should be regarded as questionable leaders. As the author quite clearly points out, the problems of engineering and even the problems of industrial management are concrete and simple to a degree not yet possible in the much broader field that we call generally the field of economics and of which the paper under discussion gives an acceptable definition. I would emphasize Dean Kimball's cautions regarding any attempt at a happy-go-lucky type of attack upon the problems of economics. The field is very broad, world-wide in fact; and the subjects that must be considered are multitudinous, intimately interlocked and in many cases imperfectly understood.

Second, while we commonly speak of the science of economics or use some equivalent name, I agree that the subject is not yet a science. Possibly I can convey my own appraisal best by saying that I believe it to be a science in the making. The recognized sciences of the present day such as physics, chemistry, biology, and many others were just as weird collections of discordant theories and opinions a short time ago as is the so-called science of economics today. In fact, one does not have to go far beyond the simplest concepts and most easily proved principles in the recognized sciences of today to find quite a bit of confusion.

To me a subject of study is worthy of being called a science when prediction of actions under assumed sets of circumstances has become possible. On this basis, I believe that modern economic studies and writings show economics to be a science in the making and probably now slowly approaching the state of development in which it properly can be regarded as a science in fact.

Third, looking at the matter through the eyes of an engineer, I believe that the study of economics has suffered from a very common failure to define terms and concepts rigorously and then to think and reason always within the terms of such definitions. The physicist and the chemist know exactly what is meant by the word atom. Different physicists and chemists may hold different views regarding the internal structure of the atom or even of its behavior under certain circumstances and the reasons therefore, but to all of them the word atom conveys a certain definite concept. I do not find any such unanimity of usage of terms used in economic writings and thought. In fact, it is shocking to me as an engineer to find an author rigidly defining some economic term at the beginning of a book or chapter thereof and then gradually sliding over to another meaning or the use of the same term for a quite different concept within the same book or even the same chapter. True sciences cannot be built upon such changing foundations.

The comparatively recent tendency to introduce mathematical methods into the field of economics undoubtedly will have a salutary effect in such respects. From one point of view mathematics is really nothing but shorthand expression for what can be put in words or thought, but it has the advantage of such stark realism that one is quickly driven to recognize confusion of definitions. When the symbol A in equation 14 of a series has taken on a different meaning from that which it had in equation 1 of the same series, something obviously is wrong.

Fourth, while the subject of economics is expressed in terms of certain impersonal concepts such as money and credit, wealth, labor, wages, rent, etc., it is in reality a sort of specialized branch of psychology. In the ultimate end it endeavors to account for certain behaviors of people in large groups. The things of which the economist speaks and writes are of importance only as they explain the behavior of the human social organism; of themselves they mean nothing at all. They are devices created by man for his own purposes; they now become so significant in his existence that many of his most important acts, movements, and reactions can be explained if we can discover all the stimuli resident in them at any given time and then interpret them correctly in terms of individual and mass reaction.

Fifth, to my mind the engineer can perform a useful service in the field of economics. But if he does it, he will do it as effort supplementing that of others rather than as an original and self-contained endeavor. In fact, any scientifically and mathematically trained individual could render a useful service at the present time by bringing in the truly scientific method: first, as a means of testing and evaluating present concepts and theories; and second, as a means of advancing in a more rigorously scientific fashion beyond the present state of the subject. Engineers with proper training and enthusiasm probably could do a still better job than pure scientists, because of their inherent desire to achieve practical working results rather than to be satisfied with explanations of why and wherefore.

But, like Dean Kimball, I want to stress the futility of engineers attempting to enter the field of economics unless they are willing to devote time and energy to the intensive and rigorous study of the history of humanity and the history of economics as a ground work for an engineering method of attack upon these entrancing, but very confusing, problems. And, in closing, permit me to caution those who are willing to undergo such rigid discipline to remember always that in this field one does not deal with equations in which parameters are expressible solely in such readily determinable things as masses, forces, fields, and the like, but that back of all of them lies that peculiar organism known as the human being. It is his reactions to stimuli of various sorts that constitute what I am sufficiently optimistic to believe will ultimately be a true science of economics.

Very truly yours,
C. F. HIRSHFELD (A'05)
(Chief of Research Dept.,
Detroit (Mich.) Edison
Co.)

Short Cuts to Finding $\sqrt{a^2 + b^2}$

To the Editor:

Many engineering calculations require the evaluation of the expression $\sqrt{a^2 + b^2}$, and sometimes a great amount of labor is expended in making this evaluation. Short-cut methods of evaluating the expression are highly desirable, providing they are accurate, or at least of known accuracy. Usually short cuts are not as accurate as the longer methods, and yet of sufficient accuracy for the work at hand, but, because they are less accurate, they are often neglected, even though time and labor could be saved by employing them. Herewith are enumerated several short-cut methods for finding $\sqrt{a^2 + b^2}$ with determinable accuracy, so that the computer may select that method which best suits his needs.

1. The method generally used to evaluate $\sqrt{a^2 + b^2}$ is simple, but laborious and time consuming; it is direct but sometimes of doubtful accuracy. It consists in using a table of squares to find a^2 and b^2, which are then added; and then again using the table to find the square root of the number nearest to the sum.

EXAMPLE: Find $\sqrt{(1{,}551.8)^2 + (726.5)^2}$. Here $a = 1{,}551.8$ and $b = 726.5$. Because of the limitations of the table of squares, the nearest number to a to be found is 155(× 10), for which $a^2 = 24{,}025(\times 100)$. Likewise the nearest number to b is 726 or 727. Using 727, $b^2 = 528{,}529$. Then $a^2 + b^2 = 2{,}931{,}029$. In order to find the square root of this number in the table it is necessary to write it as 29,310.29 × 100. The nearest square to 29,310.29 to be found in the table is 29,241, the square root of which the table gives as 171. Therefore, using the nearest tabular values $\sqrt{a^2 + b^2} = 1{,}710$. The correct value is 1,713.4.

2. The squares of the factors a and b as given by the table are sometimes sufficiently accurate for the work at hand, but taking the square root of the sum from the table is sometimes not of sufficient accuracy. A method which increases this accuracy is given in "An Easy Method of Approximating the Square Root" by C. H. Willis, JOUR. A.I.E.E., v. 48, 1929, p. 60. Let $a^2 + b^2 = A$; the problem, then, is to find $\sqrt{A}$. Write

$$\sqrt{A} = \sqrt{N^2 \pm Z} \tag{1}$$

where N^2 is the nearest number to A to be found in the table, and it may be either larger or smaller than A; and Z is the difference between A and N^2. By the binomial expansion

$$\sqrt{N^2 \pm Z} = N \pm \frac{Z}{2N} \mp \frac{Z^2}{8N^3} \pm \frac{Z^3}{16N^5} \tag{2}$$

Using only the first 2 terms there results

$$\sqrt{N^2 \pm Z} = N \pm \frac{Z}{2N} \tag{3}$$

This is quite an easy method to apply and the slide rule may be used to evaluate the fraction.

EXAMPLE: Find $\sqrt{2{,}931{,}029}$ by eq 3. The nearest square in the square column of the table is 2,924,100, therefore $N^2 = 2{,}924{,}100$, for which $N = 1{,}710$. Then $Z = 2{,}931{,}029 - 2{,}924{,}100 = 6{,}929$, and finally $\sqrt{2{,}931{,}029} = 1{,}710 + \frac{6{,}929}{3{,}420} = 1{,}712.02$, using the slide rule for the fraction. The correct value is 1,712.025. If N is so chosen that N^2 is greater than A, the minus sign must be used before $\frac{Z}{2N}$.

This method results in an accuracy somewhat higher than that from using the table alone.

3. An alternative method of evaluating $\sqrt{A}$ which is similar to method 2 has been suggested. (See "Short Methods of Extracting Roots," a letter by H. E. Eckles, *Civ. Engg.*, March 1933, p. 177.) Write the equation

$$\sqrt{A} = N + Y \tag{4}$$

where N is the largest number in the table whose square is nearest to A in value (and it must be smaller than A), and Y is a number to be found. Squaring both sides of eq 4 and solving for Y gives

$$Y = \frac{A - N^2}{2N + Y} \tag{5}$$

For the first approximation, and sometimes the only evaluation made, the Y in the denominator of the right hand member of eq 5 may be dropped.

EXAMPLE: Find $\sqrt{2{,}931{,}029}$. From the table of squares the number whose square is nearest to A in value is 1,710. Then $N = 1{,}710$, and the first approximation of Y is $Y = \frac{2{,}931{,}029 - 2{,}924{,}100}{3{,}420} = \frac{6{,}929}{3{,}420} = 2.026$. The final value of $Y = \frac{6{,}929}{3{,}422.026} = 2.025$, and $\sqrt{A} = 1{,}710 + 2.025 = 1{,}712.025$.

Eq 5 is more exact than eq 3, but a little longer in application.

4. Getting back to the original problem of direct evaluation, the value of $\sqrt{a^2 + b^2}$ may be found approximately (see article by C. H. Willis referred to under method 2) by using the first 2 terms of the binomial expansion:

$$\sqrt{a^2 + b^2} = a \pm \frac{b^2}{2a} \tag{6}$$

where a is always the larger number.

Example: Find $\sqrt{(1{,}551.8)^2 + (726.5)^2}$

$\sqrt{a^2 + b^2} = 1{,}551.8 + \frac{528{,}529}{3{,}103.6} = 1{,}724.8$, using the slide rule for the fraction.

This method requires the looking up of only one square from the table, but it is not very accurate unless a is at least 3 times as large as b. One advantage of this method, however, is that reactance, as well as impedance, may be found from eq 6. Using the plus sign $Z = \sqrt{X^2 + R^2}$ and using the minus sign $X = \sqrt{Z^2 - R^2}$.

5. A simple method (see Hudson's "The Engineer's Manual," last edition, p. 257a and 257b) has been developed from the expression

$$\sqrt{a^2 + b^2} = a + bC \tag{7}$$

where C is a constant to be determined. Solving eq 7 for C gives

$$C = \sqrt{\left(\frac{a}{b}\right)^2 + 1} - \frac{a}{b} \tag{8}$$

This constant, C, is a function of the ratio a/b, where a is the larger, and it may be determined for values of the ratio likely to be encountered in ordinary computation. This has been done for a great number of values, and tabulated against the argument b/a rather than a/b, simply for convenience. The use of this table reduces the evaluation of $\sqrt{a^2 + b^2}$ to 3 simple operations: (1) the calculation of the ratio b/a, for which the value of C is taken from the table; (2) the determination of the product bC; and (3) the final value of $a + bC$, by simple addition.

6. Besides the direct method (method 1), probably the best known and most used method, where the slide rule is used exclusively, is

$$a^2 + b^2 = b\sqrt{1 + \left(\frac{a}{b}\right)^2} \tag{9}$$

where a is the larger number. All the indicated operations can be carried out with the slide rule if the proper sequence is followed. First, the ratio of the larger number to the smaller number $\left(\frac{a}{b}\right)$ is obtained; then this ratio is squared; one is added to the square of the ratio by merely making a new setting on the rule; then the square root is extracted; and the final result multiplied by the smaller number (b). Where the accuracy of the slide rule is sufficient this method is very satisfactory, and with a little practice it becomes a fairly fast method. A great part of the work is done with the ratio a/b, and if that ratio falls below 2 it comes on the part of the slide rule which can be read to 3 places and estimated to the 4th place.

This method has one serious objection, however, which has been experienced by those who have used it, and that is, that the computer must be careful to add the one in the right place. For example, suppose $(a/b)^2 = 1.123$. Adding one makes 2.123 as the number under the radical. Suppose, however, that $(a/b)^2 = 11.23$, then the number under the radical should be 12.23. Unfortunately, however, in making many calculations, the one is often added in the wrong place, making the number under the radical 21.23. The computer must continuously guard against this tendency.

This method has been considerably simplified by a table recently computed by the author and published by the Engineers Publishing Company, Public Ledger Building, Philadelphia, Pa., and which reduces the whole evaluation to 2 operations. If the right hand side of eq 9 is multiplied and divided by a/b, there results

$$\sqrt{a^2 + b^2} = \frac{a\sqrt{1 + \left(\frac{a}{b}\right)^2}}{a/b} = a[f(a/b] = aK \tag{10}$$

The factor K has been evaluated for all values of a/b and tabulated, so that the whole operation consists simply in finding the ratio a/b on the slide rule (a is greater than b), determining the corresponding value of K from the table, and then multiplying by the larger number (a), which is already set on the rule.

The factor K has been evaluated for ratios of a/b from 1.000 to 2.999, in steps of 0.001; from 3.00 to 9.99, in steps of 0.01; and from 10 to 30 in steps of 0.5. For $a/b = 1$, $K = 1.4142$, that is, when the 2 numbers are equal the square root of the sum of the squares is 41 per cent greater than either one. For $a/b = 3.00$, $K = 1.0541$, the square root of the sum of the squares being 5.4 per cent greater than the larger number. For $a/b = 10.0$, $K = 1.0050$, the square root of the sum of the squares being 0.5 per cent greater than the larger number; and for $a/b = 50$, $K = 1.0002$. When the 2 factors, a and b, are greatly different, one can quickly determine from a glance at the table just how much the smaller number will affect the final result. The use of a table of this sort greatly reduces the labor when many computations must be made.

Very truly yours,
W. J. Seeley (A'19, M'28)
(Professor of Electrical Engineering,
Duke University, Durham, N. C.)

American Engineering Council

Private Engineers for Building Program

Announcement is made by American Engineering Council that private architects and engineers throughout the country will be engaged by the Treasury Department of the federal government to prepare plans and specifications for a large federal building program. This plan has been adopted by L. W. Robert, Jr. (A'31) assistant secretary of the treasury in charge of public buildings, in order that the work will be spread as far as possible among architects and engineers. Announcement of Mr. Robert's new activities was given in the personal columns of Electrical Engineering for July 1933, p. 515.

Mr. Robert has requested the cooperation of American Engineering Council and the American Institute of Architects in enrolling qualified individuals and firms located in the states in which the work will be done. American Engineering Council is compiling state lists of competent engineers. It has requested that any qualified engineer desiring to participate in the Treasury Department's building program send to L. W. Wallace, executive secretary, American Engineering Council, 744 Jackson Place, N.W., Washington, D. C., a complete statement, in duplicate, of his professional record, with a citation of significant references. Blanks for this purpose can be obtained from American Engineering Council. Although Council is preparing the lists, selection and employment of engineers will be the function of the Treasury Department.

Engineering Foundation

Humanistic Studies and Library Support Urged

At a joint meeting of the boards of the 4 national engineering societies of civil, mining and metallurgical, mechanical, and electrical engineers, and the board of United Engineering Trustees, Inc., at Chicago, Ill., June 27, 1933, Dr. F. M. Becket, president of the American Institute of Mining and Metallurgical Engineers, and president of the Union Carbide and Carbon Research Laboratory, New York, N. Y., urged that The Engineering Foundation consider the undertaking of engineering studies of broad social and economic import. Further, he pointed out the desirability of increasing the activities of the Engineering Societies Library. Doctor Becket's statements follow:

"The 4 Founder societies Note: The American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers have been united so long in the support of engineering investigation, that their representatives need not be reminded of the great value of research, especially cooperative research. Concerning this we all agree. Activities of this kind, fostered by the societies under the auspices of The Engineering Foundation, have been many. Splendid examples are the arch dam investigation, to cite one of the early projects lately completed, and the alloys of iron research, started about 4 years ago and still making excellent progress.

"These are examples of technical research directed largely to industrial utility. However, the view has not been so restricted. As another example, I am sure that the relatively recent services of the Foundation to engineering education are a source of general pride and satisfaction. Without explanation, it seems to me that excellent plans have been laid for the near future in this field of activity.

"While passing—those who have not,

should read the brochure entitled 'Engineering: a Career—a Culture.' It is receiving the hearty appreciation it deserves.

"Now, do any of us not believe that the social structure of the nation is taking new form? Intelligent, experienced Thomas Woodlock, in writing his Wall Street Journal column a short time ago, thought it wise to defend himself against a few critics who had objected to the use of his term "economic revolution" as defining the economic change through which we are passing. His critics desired the word 'evolution,' but Woodlock presented a very strong case. Choose what words you will, it is apparent that we are undergoing important and probably lasting changes in our economic and social structures.

"In his deed of gift, Ambrose Swasey used the expression 'For the furtherance of research in science and engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind.' Therefore, should we not plan to expend hereafter a larger proportion of our available funds in a manner appropriate to the broader point of view. If *so*, The Engineering Foundation in the future should promote investigation of problems less specific than those of the past. I am aware that this is not a new thought, since considerable discussion of this subject by The Engineering Foundation Board and others interested has taken place recently. However, may I be permitted to say that we are at a crossroad.

"There will be no difficulty in selecting the problems of greater scope. Without in the least attempting to suggest problems of more importance than many others, it has occurred to me, by way of example, that the housing problem in its broad aspect could well employ the talents of these 4 national engineering societies. The dust problem requires immediate attention for humanitarian reasons, and no branch of engineering is exempt. Here is one example —think of the toll taken by silicosis. Methods for inhibiting silicosis in the rock drilling about New York City have met with great success, at least in 1 or 2 instances. But time will not permit my support of these examples by engaging in discussion of details.

"At least until peace and plenty may return, engineering studies of broad social and economic import may well displace the more specific professional problems that have held our attention in the past. The expected benefits would be widely spread, and moral and financial support could properly be sought from all industry. May I leave the subject of humanistic engineering to your further reflections?

"While I have opportunity, I do wish to say something still more specific. There is general agreement that any investigation of importance should begin with a thorough review of the appropriate literature, and therefore the need of a well-filled library perfectly organized for rapid searching. In these respects The Engineering Societies Library is to be warmly commended, and of all the collections available for engineering study in New York City it is preferred by the technical staff with which the speaker is associated. Our library is conducted with the courtesy and efficiency appropriate to its sponsors. Nevertheless, its present usefulness for research by the engineering profession could be greatly increased through expansion of present facilities.

"With moderately increased expenditure many periodicals could be added to the present list, to great advantage, and gaps could be filled in the existing files, not now complete. I have been informed authoritatively that there are several hundred engineering periodicals, chiefly foreign, not subscribed to by any engineering library in New York. A modest amount, and in this instance, it would be for a period not longer than a year or 2, would enable a cataloging of engineering literature in other New York libraries. Our Library has much information in this respect, but much more could be obtained. It is obvious that expansion of facilities in the directions mentioned would also increase the efficiency of Engineering Index.

"If one chooses to concentrate but a short time on what could be accomplished through still larger expenditures, little difficulty is encountered, and so I do not intend to discuss a broader plan.

"With a moderate increase in annual expenditures in mind, personally, not as a representative of the mining engineers, because there has not been opportunity to discuss the subject officially, I respectfully suggest for your consideration that The Engineering Foundation direct a larger proportion of its funds to upbuilding Engineering Societies Library. Such plan may lack the appeal of publicity, but I believe there is no better object of common benefit to the 4 national engineering societies, in so far as cooperative research is concerned.

"Of course, we are all looking forward to the time when the library will have a greatly enlarged endowment fund, and need I remind you that our library services reach not only engineers in all our own States, but extend also to our engineers in many foreign countries?"

Personal Items

Paul Doty (A'04, M'12) chairman of the Minnesota State Board of Registration for Architects, Engineers, and Land Surveyors, St. Paul, Minn., has been nominated for the office of president of The American Society of Mechanical Engineers, as announced on p. 582 of this issue. He was born in Hoboken, N. J., in 1869. He graduated from Stevens Institute of Technology in 1888, with the degree of mechanical engineer, and then entered the gas industry with which he has been identified most of his life. He was a cadet engineer with the United Gas Improvement Company, Philadelphia, Pa., in 1888, and in 1889 was assistant engineer of this company for the Jersey City Gas Works. Between 1890 and 1895 he was assistant superintendent for the United Gas Improvement Company at their Paterson, N. J., gas works, and between 1895 and 1898 was general manager and vice-president of the Consolidated Gas Company of New Jersey, Long Branch, N. J., operating a combined gas and electric company. Between 1898 and 1901 he was secretary and general manager of the Grand Rapids Gas Light Company, Grand Rapids, Mich., becoming a director of the National City Bank of Grand Rapids while in this city. From 1901 to 1903 he was secretary and general manager of the Detroit City Gas Company, serving also as president of the Michigan Gas Association in 1901–02. In 1903 and 1904 he was vice-president and general manager of the Denver Gas and Electric Company, and in the latter year became vice-president and general manager of the St. Paul Gas Light Company and related companies, holding these positions until 1917. Between 1905 and 1910 he also was president of the Union Light, Heat and Power Company of Fargo, N. D. Mr. Doty served as major, corps of engineers, U.S. Army, in 1917 to 1919. In 1919 he was commissioned lieutenant-colonel, U.S. corps of engineers, and now is a lieutenant-colonel of the reserve corps of the U.S. Army. He has served continuously as chairman of the Minnesota State Board of Registration since its organization in 1921. He has been engaged actively as advisory engineer to St. Paul financial institutions, particularly as regards public utilities, and has been vice-president and managing director of the St. Paul Trust and Savings Bank. In 1906 he served as president of the Western Gas Association, and has been active in business associations in St. Paul. He is a member of the American Gas Institute, the Illuminating Engineering Society, and the Society of American Military Engineers. He has contributed a number of technical papers to gas associations.

B. E. Lowe (Enrolled Student) has received the 1932 A.I.E.E. South West District prize for Branch paper for his work entitled "Economics of Rural Line Distribution." He was born at Colorado Springs, Colo., in 1907, and received the degree of bachelor of science in electrical engineering from Oklahoma Agricultural and Mechanical College, Stillwater, in 1932. In 1933 he received the degree of master of science in electrical engineering from the same institution. While in college he received many awards. Among these are the Sigma Tau award for highest average among freshmen engineers, and a cup presented at commencement exercises for the "most valuable all-'round student of the year" among the men students of the graduating class of 1932; the Lowe scholarship award set up by Lambda Chi Alpha, national social fraternity, of which he is a member; and a scholarship offered jointly by the Oklahoma Gas and Electric Company and the State Engineering and Agricultural Experiment Station, which enabled

J. S. CARROLL

BRADLEY COZZENS

K. W. MILLER

E. M. WOOD

him to secure his master's degree. The work for this degree involved research and study in rural line design and investigation, and was a continuation of the paper "Economics of Rural Line Distribution," upon which this scholarship and also the Institute prize award were based. He also was elected to membership in Sigma Tau, national honorary engineering fraternity, of which he was president one year; Eta Kappa Nu, national honorary electrical engineering fraternity; and Phi Kappa Pi, national honorary scholastic fraternity. His college career was interrupted for nearly 3 years, during which period he was with the Southwestern Light and Power Company, first as electric distribution engineer at Lawton, Okla., then division engineer of the Chickasha, Okla., division of the company. During this time he acted as chairman of the company educational meetings for the employees, and as instructor of practical electricity in vocational education night classes for employees and others interested.

Bradley Cozzens (A'28) research engineer in the transmission line design department, Department of Water and Power, Los Angeles, Calif., has, with his co-author, J. S. **Carroll** (A'24) received the 1932 A.I.E.E. Pacific District prize for best paper, for their work entitled "Corona Loss Measurements for the Design of Transmission Lines to Operate at Voltages Between 220 Kv and 330 Kv." He was born at San Jose, Calif., in 1903. The first part of his college curriculum was finished at the College of Pacific, San Jose, where he received the degree of doctor of arts in mathematics in 1925. Here he was active in music and dramatics. Entering Stanford University, Calif., he spent 2 years in the school of engineering, the second year being devoted almost entirely to research and thesis study in high voltage. Here he received the degree of electrical engineer in 1927, being elected a member of Sigma Xi, national honorary research fraternity, at that time. Since entering the employ of the municipal water and power system of the city of Los Angeles in 1927, he has been engaged mostly in research studies of high voltage insulation. A portion of the time has been spent at the Harris J. Ryan laboratory of Stanford University. Studies investigated during the past 5 years have included long point-gaps and large sphere-gaps for the measurement of high voltages, insulation design for areas subject to severe fog conditions, the nature of self-extinguishing arcs with moderate current values, corona loss at voltages of 220 kv and above, and most recently, insulation design for the Boulder Canyon transmission line conducted in conjunction with superiors of the department. Mr. Cozzens has contributed 2 previous papers to the Institute, the first of them being a student paper.

K. W. **Miller** (A'23, M'29) director of research, Utilities Research Commission, Inc., Chicago, Ill., has received the 1932 A.I.E.E. national prize for best paper in engineering practice jointly with his co-author F. O. **Wollaston** (A'27). The title of their prize winning paper is "Thermal Transients and Oil Demands in Cables." Mr. Miller was born in Jacksonville, Ill., in 1898, and graduated from the University of Illinois in 1919 with the degree of B.S. in E.E. He later received the degree of electrical engineer from the University of Illinois in 1929, and the degree of M.S. in E.E. from Union College, Schenectady, N. Y., in 1932. Following graduation in 1919, he spent 2 years with the General Electric Company at Schenectady, being first in the test department, and later in the marine engineering department of the company. He then spent 3 years in hydro-electric construction work for the city of Seattle at the Skagit River in Washington. In the fall of 1924 he obtained employment with the street department of the Commonwealth Edison Company of Chicago, and for the last $2^1/_2$ years has served as director of research for the Utilities Research Commission, Inc. While with the Commonwealth Edison Company his work consisted principally of special studies on cables and lightning investigations on distribution networks. In 1929 he presented a paper before the Institute entitled "Reduction of Sheath Losses in Single Conductor Cables."

J. S. **Carroll** (A'24) associate professor, Stanford University, Calif., has, with his co-author, **Bradley Cozzens** (A'28) received the 1932 A.I.E.E. Pacific District prize for best paper for their work entitled "Corona Loss Measurements for the Design of Transmission Lines to Operate at Voltages Between 220 Kv and 330 Kv." Mr. Carroll was born at Orderville, Utah, in 1891. For $2^1/_2$ years following 1914 he was at the Brigham Young University, Provo, Utah, joining the engineering laboratories of the Western Electric Company, New York, N. Y. in 1916. In 1917 he entered the United States Army as a volunteer and served 19 months in the signal corps. His rank at the time of his honorable discharge was sergeant, first class. In 1920 he received the degree of B.S. in E.E from the University of Utah. The summer of 1920 was spent in the testing department of the General Electric Company, Schenectady, N. Y. At the University of Utah he was campus engineer and instructor in the electrical laboratory, 1920–21; instructor in the physics laboratory, 1921; and instructor in electrical engineering, 1921–23. He held the Elwell fellowship in electrical engineering at Stanford University in 1923–25, and was granted the degree of electrical engineer, 1924. Between 1924 and 1926, he was instructor and graduate student at Stanford University, becoming assistant professor there in 1926, and associate professor in 1930. In 1921 he received the degree of doctor of philosophy from Stanford University. Since the retirement of Dr. **Harris J. Ryan** (A'89, F'33, member for life, and past-president) in 1931, he has been in active charge of the Ryan high voltage laboratory at Stanford University.

E. M. **Wood** (A'09, M'25) designing engineer in the station section, electrical engineering department of the Hydro-Electric Power Commission of Ontario, Canada, has received the 1932 A.I.E.E. Canada District prize for best paper for his paper "Some Notes on Modern Relay Protection." He was born in Norfolk County, Ontario, Canada, in 1882, and in 1908 received the degree of bachelor of applied science in mechanical and electrical engineering from the University of Toronto, Canada. He served an apprenticeship in the factory and testing departments of the General Electric Company at Pittsfield, Mass. In 1910 he was factory inspector of electrical equipment for the Hydro-Electric Power Commission of Ontario, and between 1910 and 1913 was assistant to the superintendent of inspection of the Canadian General Electric Company, Toronto, being in the field construction and service sections of the engineering department. Between 1913 and 1917 he was engineer in charge of the complaint section, engineering department, of the Canadian General Electric Company. Be-

T. M. AUSTIN

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F. O. WOLLASTON

tween 1917 and 1919, he was operating and safety engineer of the Consolidated Mining and Smelting Company, Trail, British Columbia. Since 1919 he has been designing engineer in the station section for the Hydro-Electric Power Commission, giving especial attention to system arrangements and relaying. He has been on the executive committee of the Toronto Section of the Institute for several years, being chairman of the Section for the year 1928–29. He is vice-president of the membership committee of the A.I.E.E. for the Canada District, and is a member of the Institute's protective devices committee.

J. W. McRae (Enrolled Student) has been awarded the 1932 A.I.E.E. Canada District prize for Branch paper for his work entitled "The Parallel Type Thyratron Inverter." He was born in Vancouver, B. C., in 1910, and after serving as laboratory assistant in Vancouver Technical High School for 2 years following graduation from that institution, spent one year studying for the senior matriculation examinations of the University of British Columbia. He then returned to the Vancouver Technical School as instructor in the electrical department for the year ending in 1929. That year he entered the faculty of applied science at the University of British Columbia, receiving the degree of B.A.Sc., with honors, in 1933. Since entering the university he has taken an active interest in the various engineering organizations on the campus and was a junior member of the executive committee of the local Branch of the Institute during 1931–32, and was chairman during the 1932–33 session. At the same time he was president of the Science Men's Undergraduate Society. During the summer of 1930 he was in the maintenance department of the British Columbia Telephone Company and during the summer of 1932 he was in charge of a series of tuition classes in engineering subjects arranged by the Association of Professional Engineers of British Columbia for their non-university students. During the coming session he will do post-graduate work at the California Institute of Technology, where he has been awarded a graduate assistantship. He has won 8 scholarships and prizes awarded by the University of British Columbia, totaling $725. These include 2 prizes for papers, 3 prizes for general proficiency, and a prize awarded to the student in the graduating class in the faculty of applied science whose record in the opinion of the faculty is the most outstanding.

E. G. Cullwick (A'26) assistant professor of electrical engineering, University of British Columbia, Vancouver, B. C., has been awarded the 1932 A.I.E.E. Canada District prize for initial paper for his work entitled "Theory of the Three-Wire D-C Generator With Two-Phase Static Balancer." He was born in Wolverhampton, England, in 1903, and graduated from Cambridge University, England, in 1925 with honors in mathematics and mechanical sciences. He was a foundation scholar of Downing College, Cambridge. From 1925 to 1926 he was student apprentice with the British Thomson-Houston Company, Rugby, England, and for the following 2 years until 1928 was with the Canadian General Electric Company, Peterboro, Ontario, Canada. Since 1928 he has been at the University of British Columbia as assistant professor of electrical engineering. He has received honorable mention in both 1931 and 1932 in connection with the past-president's prize competition of the Engineering Institute of Canada. In 1930 he founded the Student Branch of the Institute at the University of British Columbia, and has been counselor since its inception. In 1932 he was chairman of the student activities committee of the Pacific Coast convention of the A.I.E.E. Mr. Cullwick is an associate member of the Institution of Electrical Engineers, England.

F. W. Cooper (A'33) has, with his coauthor, T. M. Austin (A'33), received the 1932 A.I.E.E. national prize for Branch paper for their work entitled "The Application of Inductive Non-Linear Circuits to Some Electrical Engineering Problems." Mr. Cooper was born at Cottesmore, Rutland, England, in 1905. Following primary and secondary education in the schools of England, he became junior test man at the works of Peel-Conner Telephone Company, Coventry, Warwickshire, England, in 1925, remaining until the following year. In 1926 he entered the United States. Following an illness, he entered the University of Colorado as a student in electrical engineering in 1929, and in 1932 received the degree of B.S. in E.E., with special honors. He was then awarded a University of Colorado fellowship in electrical engineering in 1932, and received the degree of master of science in electrical engineering in 1933. At the University of Colorado, he was president of the student council, 1931–32; president of the Colorado Beta Chapter of Tau Beta Pi, 1931–32; and chairman of the University of Colorado Branch of the A.I.E.E., 1931–32. He is also a member of Sigma Tau, Eta Kappa Nu, and an associate member of Sigma Xi. Mr. Cooper, not actively employed at present, has received first naturalization papers in the United States.

F. O. Wollaston (A'27) research division, engineering department, Commonwealth Edison Company, Chicago, Ill., has, with his co-author K. W. Miller (A23, M'29) received the 1932 A.I.E.E. national prize for best paper in engineering practice for their work entitled "Thermal Transients and Oil Demands in Cables." Mr. Wollaston was born at Victoria, B. C. in 1903, and received the degree of B.S. in E.E. from the college of engineering, University of Washington, in 1925. In 1931 he received the degree of electrical engineer from the same institution. Following graduation he spent a year in the student course of the Commonwealth Edison Company in Chicago. He has been associated with the Commonwealth Edison Company ever since, first in the street department and more recently in the research division, engineering department.

T. M. Austin (A'33) who, with his coauthor F. W. Cooper (A'33), was awarded the 1932 A.I.E.E. national prize for Branch paper for their work entitled "The Application of Inductive Non-Linear Circuits to Some Electrical Engineering Problems" is a graduate assistant in electrical engineering at Iowa State College, at Ames. He was born at Huntley, Mont., in 1911, and received the degree of B.S. in E.E. from the University of Colorado in 1932. The master of science degree is being granted him August 1933 upon completion of minor work at Iowa State College. He is a member of the following honorary fraternities: Tau Beta Pi, Eta Kappa Nu, Sigma Xi, Kappa Kappa Psi. While an undergraduate he was in several student activities.

W. A. Lewis, Jr. (A'27) general engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has, with his co-authors S. B. Griscom and W. R. Ellis, received honorable mention in connection with the 1932 A.I.E.E. national prize for best paper in engineering practice, for their work entitled "Generalized Stability Solutions for Metropolitan Type Systems." Mr. Lewis was born at Harriman, Tenn., in 1904. He entered the employ of the Westinghouse Electric and Manufacturing Company in the Los Angeles Calif., service shops in 1920, being electrical draftsman and switchboard engineer. In 1922 he received a Westinghouse war memorial scholarship contributing toward a 4-year course in engineering at the California Institute of Technology, Pasadena. Following graduation in 1926, with further aid from the Westinghouse Electric and Manufacturing Company and the California Institute of Technology, he continued studies for 3 additional years, receiving the degree of doctor of philosophy "summa cum laude" in 1929. During summer vacations he secured experience with the Westinghouse company, and also with the Stone and Webster Engineering Corp., and Bureau of Power and Light of the city of Los Angeles. Since 1929, Mr. Lewis has been in the central station engineering department of the Westinghouse company at East Pittsburgh, specializing in transmission and relaying problems, steam railroad electrifications, etc. He is the author or co-author of 4 A.I.E.E. papers (1929, 1931, 1932 (2)).

P. L. Bellaschi (A'29) development and research engineer, Westinghouse Electric and Manufacturing Company, Sharon, Pa., has received honorable mention in connection with the 1932 A.I.E.E. national prize for initial paper for his work entitled "Characteristics of Surge Generators for Transformer Testing." Mr. Bellaschi was born in Piedmont, Italy, in 1903, where he attended grammar school. He immigrated to America in 1913 and for the following 10 years spent part of the time working at various occupations and part of the time at school preparing for entrance to a technical institution. He graduated from Massachusetts Institute of Technology in the electrical engineering course in 1926. The year following graduation he was on the student course of the Westinghouse Electric and Manufacturing Company, returning to M.I.T. where he received the degree of master of science in 1928. Returning to the Westinghouse company he spent 8 months on radio development and since then has been engaged in development and research on high voltage transient phenomena at the transformer plant of the company at Sharon. Mr. Bellaschi is a member of the Associazione Elettrotecnica Italiana, and has contributed technical articles to Italian journals.

W. J. McLeod (A'33) Oakland, Calif., has received the 1932 A.I.E.E. Pacific District prize for Branch paper for his paper entitled "The Precise Electrical Measurement of Short Time Intervals." He was born in Chicago, Ill., in 1910. After attending Oakland Technical High School, Oakland, Calif., he entered the University of California, graduating with the degree of bachelor of science in electrical engineering in 1932. In 1933 he received the degree of master of science in electrical engineering at the same institution, having specialized in communications. His prize winning paper covered part of his work in an original investigation of the interior ballistics of the Springfield rifle. This work was done as his thesis for the bachelor's degree, and was later continued as research for the master's degree. Mr. McLeod holds a commission as second lieutenant, Ordnance Reserve, and is a member of Tau Beta Pi (engineering), Sigma Xi (science), and Eta Kappa Nu (electrical engineering). He was a delegate to the 1931 national convention of Eta Kappa Nu at Cornell University, and has served the Institute as treasurer of the University of California Branch.

E. R. Gaerttner (Enrolled Student) has, with his co-author, Irwin Olcott (Enrolled Student) received the 1932 A.I.E.E. North Central District prize for Branch paper for their work entitled "Magnetism and Diamagnetism." Mr. Gaerttner was born in Denver, Colo., in 1911, graduating from the University of Denver in 1932, with the degree of B.S. in E.E. The prize winning paper was based upon work done by him and Mr. Olcott during the senior year at the University of Colorado. In the summer of 1932, Mr. Gaerttner spent 10 days at Summit Lake, Colo., where measurements were taken in connection with Dr. A. H. Compton's world-wide survey of cosmic radiation. In 1932 he entered the University of Michigan, Ann Arbor, to earn a master's degree in physics, this work having just been completed. Mr. Gaerttner hopes to return to the University of Michigan this fall to continue his work in theoretical physics.

L. A. S. Wood (M'24) manager of the lighting products division of the Westinghouse Electric and Manufacturing Company, Cleveland, Ohio, has been elected a vice-president of the Illuminating Engineering Society. He will assume his office in the society October 1, 1933. Born in England, Mr. Wood gained his technical education at the University of London, and entered the employ of the Edison Swan United Electric Light Company, which is stated to have introduced incandescent lighting into Great Britain. In 1911 he came to America to introduce a type of arc lamp and subsequently became associated with the Westinghouse company.

J. F. Neild (A'13, M'20) electrical engineer, Toronto Transportation Commission, Ontario, Can., has been elected president of the Toronto Electric Club. He is a member of the American Transit Engineering Association, and is vice-chairman of the standing committee on power, and of its committees on trolley wire wear and trolley construction specifications. He is a member of the Canadian Engineering Standards Association's committees on power transformers, specifications, power cables, sub panel on outside wiring rules, and sub panel on conductive coordination.

Harry Reid (A'22, F'31) formerly president of the National Electric Power Company and the National Public Service Corporation, New York, N. Y., has organized the firm of Harry Reid and Company, Inc., of New York. The company will engage in the operation, engineering, and supervision of public utility companies and will furnish reports and plans on construction, rates, taxes, recapitalization, and reorganization.

Bancroft Gherardi (A'95, F'12, past-president) vice-president and chief engineer, American Telephone and Telegraph Company, New York, N. Y., received the honorary degree of doctor of engineering from the Polytechnic Institute of Brooklyn, N. Y., June 14, 1933. As announced in Electrical Engineering for January 1933, p. 63, Doctor Gherardi was awarded the A.I.E.E. Edison Medal for 1932 during the Institute's 1933 winter convention.

H. H. Porter (A'96, M'12 and life member) president of the American Water Works and Electric Company, Inc., New York, N. Y., and a member of the board of The Engineering Foundation, has been elected a director of the newly organized Penn Southern Power Company which takes over the assets of 5 operating companies formerly controlled by the Insull system.

M. H. Frank (A'17) who has been assistant to the vice-president, Wisconsin Power and Light Company, Madison, since 1930, has been appointed division manager of the company at Beloit. He has been identified with the Wisconsin Power and Light Company and its predecessor, the Eastern Wisconsin Electric Company, since 1918.

R. E. Simpson (A'16) electrical and mining engineer, Travelers Insurance Company, Hartford, Conn., has retired from active service with that company. He has been with that organization promoting adequate illumination in buildings and on the highways for the past 20 years. He plans to devote his time to consultation on public illumination and industrial safety.

G. S. Diehl (A'17) assistant to the superintendent of operation, Pennsylvania Water and Power Company, Baltimore, Md., has received the James H. McGraw Award in engineering for 1933. This award of the National Electric Light Association was announced at the recent convention of the Edison Electric Institute.

W. J. Lyman (A'25) electrical planning engineer, Duquesne Light Company, Pittsburgh, Pa., has received the 1933 Gold Medal of the Henry L. Doherty Award of the National Electric Light Association, as announced at the recent convention of the Edison Electric Institute.

R. A. Hopkins (M'19) formerly electrical engineer, Stone and Webster Engineering Corp., Boston, Mass., is a member of the newly established consulting electrical and mechanical engineering firm of Hopkins and Gove, with headquarters at Waltham, Mass.

F. A. Merrick (A'07) president, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., received the honorary degree of doctor of engineering from Lehigh University, Bethlehem, Pa., at the recent commencement exercises for 1933.

H. C. Abell (A'03) vice-president, Electric Bond and Share Company, New York, N. Y., and president of the National Power and Light Company, New Orleans, La., has been nominated as a director of the American Gas Association for a 2-year term.

H. F. Kortheuer (M'21) engineer, Bell Telephone Laboratories, Inc., New York, N. Y., retired from active service July 1, 1933, after long association with the Bell system. Mr. Kortheuer had been with the system for 36 years.

W. C. Beckjord (A'12) vice-president and general manager, Boston Consolidated Gas Company, Boston, Mass., has been nominated a director of the American Gas Association for a 2-year term.

F. C. Freeman (M'17) president of the Providence Gas Company, Providence, R. I., has been nominated a director of the American Gas Association for a 2-year term.

Frank William Peek, Jr. (A'07, M'13, F'25) retiring A.I.E.E. director, died in Canada July 27, 1933 as the result of an accident. A biographical sketch will appear later.

Obituary

Harold DeForest Arnold (M'16, F'29) director of research, Bell Telephone Laboratories, Inc., New York, N. Y., died July 10, 1933. He was born in Woodstock, Conn., in 1883. From Wesleyan University, Middletown, Conn., he received the degree of bachelor of philosophy in 1906, and that of master of science in 1907; in 1911 he received the degree of doctor of philosophy from the University of Chicago. During the year1906–07, he was assistant in physics at Wesleyan University, and between 1907 and 1909 was fellow in physics and assistant in physics at the University of Chicago. During the year 1909–10, he was professor of physics at Mt. Allison University, Sackville, New Brunswick, and in 1910 was assistant in physics at the University of Chicago. After receiving his doctor's degree in 1911, he entered the engineering department of the Western Electric Company. Here he was research engineer in charge of research in electronics, magnetics, acoustics, and electrical transmission, until 1924; in 1925 he became director of research of the Bell Telephone Laboratories, Inc. While with these 2 organizations, both affiliated with the American Telephone and Telegraph Company, Doctor Arnold has contributed many important inventions for the extension of telephony. He first was interested in the telephone repeater problem, and after producing a repeater element employing a mercury arc in 1912, he undertook the development based on DeForest's 3-electrode audion, which resulted in the production of the 3-electrode high vacuum thermionic tube. These tubes were first adapted for transcontinental communication in public service early in 1915, and were quickly adopted for radio transmission. He also had a part in the development of the magnetic alloys, permalloy, and perminvar. Under his efficient direction, not to mention his very definite contribution of ideas, fundamental research upon many phases of the communication art has been carried on. These have notably advanced the whole telephone art, both wire and radio, have improved land and submarine cable telegraphy, have aided individuals having impaired hearing, and have given new methods of recording sound, thus improving phonograph records and the talking moving pictures. Doctor Arnold served as a captain in the United States Signal Corps in 1917. He was a fellow of the American Physical Society, the Acoustical Society of America, and the American Association for the Advancement of Science. He was a member of the Franklin Institute, the American Chemical Society, Phi Beta Kappa, Sigma Xi, and Gamma Alpha fraternities. In 1928, Doctor Arnold received the John Scott medal in recognition for his work on the development of the 3-electrode high vacuum thermionic tube. He served the Institute as a member of its electrophysics committee 1917–22 and a member of its research committee 1927–33.

Alexander Churchward (A'03, F'31) technical director and designing engineer for the Wilson Welder and Metals Company, Inc., North Bergen, N. J., died July 12, 1933. He was born at Colombo, Ceylon, India, in 1862. After studying in England, he came to New York City at the age of 18 and began his career as an electrician. He continued to study and between 1889 and 1890 went through the shops of the Crocker-Wheeler Electric and Manufacturing Company to learn American shop practice. Between 1890 and 1891 he was designer of electric motors for the Riker Motor Company, Brooklyn, N. Y. Between 1891 and 1893 he was with the Crescent Electric Company, Brooklyn, designing motors and dynamos, and between 1893 and 1897 he was with the Excelsior Electric Company in a similar capacity. The Excelsior Electric Company was bought out by the General Electric Company, and between 1897 and 1898 Mr. Churchward was with the Fort Wayne Electric Company, designing self-starting single phase motors and rotary converters. When this company was purchased by the General Electric Company he joined the Siemens and Halske Company of America, being with the latter company from 1898 to 1900 as chief engineer and designer, to replace the German design by his own design known as the Churchward type. When this company, too, was purchased by the General Electric Company, he joined the organization of the latter with the privilege of taking outside consulting work, remaining in this capacity between 1900 and 1903. Between 1903 and 1908 he was consultant to Thomas A. Edison on automobile motors to be used with the Edison battery. Between 1911 and 1916 he designed the Gray and Davis lighting, starting, and ignition system for gasoline cars, and between 1916 and 1917 designed the A.B.C. and Ford lighting and starting system for Ford cars. This model was used for many years. Between 1917 and 1918 he was assistant chairman of the welding committee for the Emergency Fleet Corporation. Shortly afterward he joined the organization of the Wilson Welder and Metals Company, being technical director since 1921. Some 200 patents have been taken out by Mr. Churchward, covering a variety of subjects. He has presented papers before the Institute on automobile starting systems and on electric welding systems. He has served the Institute as a member of its electrical machinery committee 1918–21, and a member of the welding committee 1927–33. He was a member of the Engineers' Club of New York.

Louis F. Leurey (A'07, M'27) consulting electrical engineer, San Francisco, Calif., died July 7, 1933. He was born in Baton Rouge, La., in 1881. In 1902 he graduated in electrical engineering from The Toulane University of Louisiana, at New Orleans, and continued in postgraduate work at the same university for 5 months. He then spent a year and a half in the testing department of the General Electric Company, Schenectady, N. Y., followed by one year in general electrical contracting work. In 1905 he joined the organization of Sanderson and Porter, New York, N. Y., as electrical engineer in erecting and operating the power system of the New Orleans Railway and Light Company. In 1907, he was assigned by Sanderson and Porter to the construction of a 12,000-kva hydroelectric plant of the Spokane and Inland Railroad Company, Spokane, Wash., and in 1908 became assistant electrical engineer with the same firm on the construction and operation of the 32,000-kva Stanislaus power plant in California. In 1909, he was appointed resident engineer on the construction of a high voltage substation at San Francisco, Calif., and in 1910 was assistant resident engineer in the construction of a hydroelectric plant on Vancouver Island, British Columbia. In 1912 he left the firm of Sanderson and Porter, becoming electrical engineer for the British Columbia Electric Railway Company, and in 1913 became assistant engineer of the civil engineering department, in charge of foundations, for the Panama Pacific International Exposition in San Francisco. Between 1914 and 1916, he was assistant chief mechanical and electrical engineer of the exposition, in responsible charge of all construction and operation of electric and gas utilities and mechanical plants. Since 1917 he has been a consulting electrical engineer in private practice in San Francisco. Here he maintained a diversified practice consisting of industrial applications of electricity, and design and supervision of power plants, valuation, and administrative engineering work. He was a member of the Institute's committee on legislation affecting the engineering profession, 1931–33. He was a past-president of both the Engineers' Club of San Francisco, and the San Francisco Electrical Development League.

Charles William Hutton (A'99, M'03, F'13) president and manager, Electrical Facilities, Inc., Oakland, Calif., died December 23, 1932. He was born in Vacaville, Calif., in 1869, and graduated from a special one-year commercial course at the California Normal College, Vacaville. In 1890 he entered the employ of the United Edison Manufacturing Company, of California, as wireman, being advanced to the position of foreman about a year later, and was subsequently superintendent of construction, installing small Edison 3-wire lighting plants. Between 1893 and 1894 he was engaged in electric railway work in California for this company. In 1894 he left the employ of the General Electric Company, which in consolidating with the Thomson-Houston Company had absorbed the United Edison Manufacturing Company, and took the position of chief electrician of the Capital Gas Company of Sacramento, Calif., being engaged on the rebuilding of their electric plant. In 1896 he took a similar position with the Sacramento Electric Power and Light Company, and in 1897 was advanced to superintendent of the electrical department. When this company was absorbed by the Pacific Gas and Electric Company he became superintendent of the Sacramento power division of the latter company, and at the same time filled the position of assistant manager of the Sacramento Electric Gas and Railway Company. In 1908 he became engineer of operation and maintenance of the Great Western Power Company's hydroelectric transmission system, and in 1909 became superintendent of the construction of the 110,000-volt Bay Shore substation in San Francisco of the Sierra and San Francisco Power Company for the firm of Sanderson and Porter. In 1910 he became Pacific Coast representative of the General Vehicle Company, Inc., of Long Island City, N. Y., manufacturers of electric vehicles. Subsequently he became president and manager of Electrical Facilities, Inc.

Ernest Julius Bechtel (A'97, M'00, F'13) retired engineer and operator of public utility properties and residing at New Rochelle, N. Y., died June 25, 1933. He was born in Des Moines, Iowa, in 1870. He was educated in the public schools and Capital City Commercial College of Des Moines, and more particularly, by home study of electrical subjects. He started work in 1887 for the Hess Electrical Company of Des Moines as general wireman and repairing electrical apparatus in the shop. In 1889 he became armature winder and electrical repairman for the Des Moines Street Railway Company. In 1891 he became assistant electrician for the Citizens Street Railway Company of Indianapolis, Ind., remaining there until 1894, working on the conversion of the line to electric operation. In 1894 he became electrical engineer for the Toledo Consolidated Street Railway Company, Toledo, Ohio, and its successor companies, the Toledo Traction Company and the Toledo Railway and Light Company. Here he remained until 1907 consolidating the street railway companies and lighting companies. He served as superintendent of power stations for a time, and built much of the underground distribution system. Later he was manager of the power and light department of the company. From 1907 until his retirement 2 years ago, Mr. Bechtel was associated with Hodenpyl, Walbridge and Company, later Hodenpyl, Hardy and Company, and held vice-presidencies in several traction, power and light companies in which the firm was interested. In 1913 he was consulting electrical engineer of all properties and vice-president in charge of operation of 10 electric and street railway properties of Hodenpyl, Hardy and Company, with headquarters in New York, N. Y. He belonged to many engineering societies. His clubs included the Engineers' Club of New York, New York Athletic Club, and Railroad Club of New York.

Walter Arnstein (A'07) consulting engineer, San Francisco, Calif., died recently. He was born in San Francisco, Calif., in 1883, and graduated in 1902 from the electrical engineering course of Sheffield Scientific School, Yale University, New Haven, Conn., with the degree of doctor of science. He then spent 2 years as an apprentice in the works of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., followed by a few months as electrical engineer in the Worthington works in Harrison, N. J. He then became engineer and assistant to the president for various electric railways all controlled by the same people; these included the Truckee River Electric Company, American River Electric Company, and Central California Traction Company. He later became secretary for the Central California Traction Company and the City Electric Company, also controlled by the same interests, and was associated in the development of the Oakland, Antioch and Eastern Electric Railway, of which he became president. Later he participated in opening the Bully Hill group of mines. In recent years he engaged in consulting engineering.

Albert Edwin Alkins (A'03, M'12) assistant to the electrical superintendent, General Electric Company, Lynn, Mass., died July 4, 1933, at Swampscott, Mass. He was born in 1874 at Germantown, Philadelphia, Pa. He studied at Germantown Academy, and spent 2 years at Ohio State University in a mining engineering course, between 1896 and 1898. After leaving college he became an apprentice in the erection department of the Cramp Ship and Engine Building Company, Philadelphia, Pa., and in 1899 entered the employ of the General Electric Company, being in their electrical course at Schenectady, N. Y., and Lynn. In 1901–02 he was in charge of special lamp testing at Lynn, and in 1903–04 was assistant in charge of all special testing at this works. In 1905 he was foreman of the special testing department and invented a d-c cradle dynamometer for power measurements. In 1906 he became assistant foreman of the general testing department and assistant to the electrical superintendent of the Lynn works, and has held the latter position since that time.

Roberto Juan Urie (M'29) director de Alumbrado y de Instalaciones Electricas y Mecanicas, Municipality of Tucuman City, Argentine, South America, died April 30, 1933. He was born at Ayacucho, Province of Buenos Aires, Argentine, in 1886. He secured his elementary education at English and North American schools in the city of Buenos Aires, and in 1903 completed the national college course of secondary education in that city. In 1910 he completed the first year in civil engineering at the faculty of engineering of Buenos Aires University. In 1915 he completed courses in electrical and mechanical engineering at the Royal Technical College, Glasgow, Scotland, acquiring practical experience at the same time in various departments of the North British Locomotive Company in Glasgow. Between 1915 and 1916 he was assistant in the technical office of the Argentine State Railways Works at Tafi Viejo. In 1916 he became Director Tecnico de Instalaciones Electricas y Mecanicas, Tucumas, Argentine Republic.

Charles V. Lenehan (A'29) assistant superintendent of substation district No. 3 of The New York Edison Company, New York, N. Y., died June 26, 1933. Mr. Lenehan was born in New York City in 1881 and in 1899 entered the employ of The New York Edison Company. For 34 years he was actively engaged in the operation and development of substations for this company. He is better known throughout the utility field for his educational activities, being connected with this phase of work since 1923. He organized the school for training substation employees and actively engaged in its curriculum until 1931. Mr. Lenehan was exceedingly interested in the general educational activities of the company and associated actively in this work until 1931 when due to additional duties being undertaken he was obliged to reduce these activities. He was a member of the company educational committee.

Charles A. McGeehan (A'13) professor of electrical engineering and head of the department, Villanova College, Villanova, Pa., died June 30, 1933. He was born in Scotland in 1880. Following 4 years in the preparatory and classical departments of Villanova College, he studied electrical engineering there for 4 years, graduating with the degree of bachelor of science in 1912. He then became an instructor in the electrical department at Villanova College, and subsequently rose to the position of head of the department.

Local Meetings

Past Section Meetings

Akron

Address by H. P. Charlesworth, pres., A.I.E.E., asst. chief engr., A. T. & T. Co. Election of officers: P. C. Smith, chm.; V. W. Shear, secy.; H. H. Schroeder, treas. May 17. Att. 160.

Cincinnati

Some Phases of Technocracy, by Dr. W. B. Kouwenhoven, vice-pres., A.I.E.E., Johns Hopkins Univ. Election of officers: L. C. Nowland, chm.; M. S. Schneider, secy.-treas. June 8. Att. 74.

Detroit Ann-Arbor

Election of officers: R. Foulkrod, chm.; H. P. Seelye, vice-chm.; J. R. North, secy.-treas. June 17. Att. 35.

Lehigh Valley

Meeting of Board of Managers. May 10. Att. 16.

Mexico

Cosmic Radiations, by M. Sandoval Vallarta. Illus. Dinner. June 29. Att. 38.

Niagara Frontier

Meeting of Executive and Program Committees. June 2. Att. 7.

Sharon

Submarine Treasure Hunting With Underwater Lamps, by E. W. Beggs, Westinghouse Lamp Co. June 15. Att. 200.

Urbana

Election of officers: H. N. Hayward, chm.; L. L. Smith, vice-chm.; H. A. Brown, secy.-treas. May 22. Att. 13.

Vancouver

Election of officers: L. B. Stacey, chm.; F. J. Bartholemew, vice-chm.; D. M. Johnstone, secy. June 5. Att. 47.

Past Branch Meetings

Harvard University

Corona Discharge, by A. K. Wright; High Spots at the Schenectady District Meeting, by E. A. Walker, students. Election of officers: S. A. Smith, chm.; R. H. Packard, secy.-treas. May 26. Att. 11.

University of Kansas

Election of officers: Edward Hubrig, chm.; Charles Smith, vice-chmn.; R. C. Oliver, Jr., secy.; Robert Ganoung, treas. May 18. Att. 46.

University of Louisville

Electrical Installations at the World's Fair, by Mr. Spalding, student. June 16. Att. 11.

Milwaukee School of Engineering

Hydroelectric Power Plants, by W. J. Rheingaus, Allis-Chalmers Mfg. Co. Election of officers: Hamilton Treadway, pres.; Byron Stratton, Jr., vice-pres.; Chester Boesewetter, treas.; J. B. Polastro, secy. June 14. Att. 85.

College of the City of New York

Vertical Transportation, by Sidney Otis, Otis Elev. Co. May 4.

Domestic Air Conditioning and Electric Refrigeration, by W. M. Timmerman, Gen. Elec. Co. Election of Officers: Philip Cohen, chm.; Robert Teter, vice-chm.; John O. Cully, secy.; Harold Kaufman, treas. May 18.

Stanford University

Inspection trip through the Gen. Elec. Co. works in Emeryville. May 15. Att. 15.

Inspection trip through the new 50,000 watt transmitting station of KPO in San Mateo. May 19. Att. 40.

Two day trip to the Mokelume River project of the Pacific Gas & Elec. Co., and the developments at Tiger Creek, Electra, and Salt Springs Dam. May 20–21. Att. 10.

Inspection trip through the substation of the Pacific Gas & Elec. Co. at Newark, Calif. May 22. Att. 20.

Experiences and Observations While on a Trip in the East, by W. C. Smith, Gen. Elec. Co. Illus. May 18. Att. 19.

Controlling the Resonate Frequency of a Circuit by Electrical Means, by W. N. Eldred; Loud Speaker Diaphragms and Their Distortion, by M. R. Jones; Filters, by S. B. Pickles; The Economic Relation Between Steam and Hydroelectric Power, by O. M. Wight; Eliminating Errors in the Dibdin Photometer, by H. S. Dixon; Variations in Corona Loss Under Controlled Atmospheric Conditions, by G. W. Dunlap, students. Election of officers: E. H. Schoenfeld, chm.; L. J. Lewis, vice-chm.; P. Lebenbaum, Jr., secy.-treas. June 1. Att. 15.

University of Washington

Stage Lighting, by James Hicken, student. Election of officers: Ray Pardo, chm.; J. M. Fluke, vice-chm.; E. Allen Loew, secy.-treas. May 12. Att. 27.

The Mercury Vapor Process, by Mr. Heinz, Gen. Elec. Co.

University of Wisconsin

Election of officers: Wallace Gates, pres.; Walter Fritts, secy.-treas. Prof. Daniel W. Mead described some of his experiences in engineering. May 25. Att. 37.

Employment Notes

Of the Engineering Societies Employment Service

Men Available

Construction

PRACTICAL ELEC CONSTR FOREMAN, 32, single, desires work along elec constr and maintenance lines. Fourteen yrs practical experience in the erection, constr and operation of industrial plants and mines. Last 4 yrs spent in mining camps in So Am. Working knowledge German, Spanish. Willing to travel anywhere. Available immediately. Location immaterial. C-2101

E.E. GRAD, 1922, 7-yr experience on central station and substation constr and installation of elec equip. 3 yrs experience on elec testing in d-c and a-c substations. East or Middle West preferred. D-2328

Design and Development

B.S. in E.E., 30, married, G.E. test and research experience. Would like research or devpt work with small concern with opportunity for advancement. D-1486

ELEC-MECH ENGR with metallurgical knowledge. Col grad with post-grad study; 30, married. Westinghouse design training. Six yrs experience design elec circuits and mech details of control apparatus, specialized in elevator equip. Interested in alloy welding research. Location immaterial. Available on short notice. C-9638

ELEC DESIGN ENGR, grad Worcester Poly Inst. Twenty yrs experience, design, development of d-c machy with 3 leading mfrs. Recently developed axle driven generator used extensively for operation of air conditioning equipment of ry trains. 5 yrs teaching. Desires position, designing engr with elec mfr or teacher in engg col. B-3318

GRAD ENGR, 32, married, desires position dealing with industrial plant design or devpt. Experience: 3 yrs designer and draftsman Sheel Petroleum Corp., 2 yrs designer and draftsman Anaconda Copper Co., 1 yr city of Seattle Engr Dept, 1 yr shop mechanic, 2 yrs telephone switchboard testing. Go anywhere, Pacific Coast preferred. C-4015

Executives

GEN MGR OR GEN SUPT, 38 yrs old. Grad elec engr. Seventeen yrs experience in engg constr, organizing and mgmt; particularly the util field. Desires position with large industrial concern or util with organizing and supervising responsibilities. B-2885

ILLUM ENGR, 38, single, B.S.E. (E.E.), '25, B.A. in Ed., '32, Univ. of Mich., desires situation illuminating and wiring design or teaching mathematics or elementary elec. Two yrs util substation operation, constrn, maintenance and administration; 4½ yrs ltg layout, devpt and contact experience. I.E.S. course in architecture, 1930. Any location. D-2208

COST REDUCTION ENGR, B.S. and M.S. deg in engg, 30, single. Eight yrs experience large mfg plant. Experienced, invention, design, installation of labor saving equip, cost reduction methods. Also welding specialist, practical experience, all methods of welding and extensive research on arc welding methods and materials. Exec experience and best references. D-2284

B.S. in E.E., married, 44; 4 yrs experience asst supt overhead distribution; 6 yrs as E.E. with mfr of elevator accessories, desires position with util or mfr. Location preferably Midwest or West. Available on short notice. D-2258

ELEC ENGR, E.E. deg. Fourteen yrs experience utilities covering valuation work, rate investigations, engg pwr plants, substations, transmission lines, including estimates, specifications, design. Experience covers short circuit studies, stability analysis, investigations of systems for load conditions. Desires position, holding co, operating co or engg firm. Available immediately. C-9570

POWER PLANT SUPT, Grad E.E., 48, married. Three yrs test and factory experience, 20 yrs industrial plants, 15 of these in charge of plants up to 50,000-kw capacity. Ten yrs in present location in charge of large pulverized coal burning plant. Both Westinghouse and G.E. turbines. C-4313

E.E. GRAD, 40, married, 14 yrs experience design, layout, installation, maintenance, elec equip in pwr house and substations, 6 yrs experience design, production, test of elec controllers, desires responsible permanent position with util, contractor, industrial plant or mfr. Location eastern states. Available immediately. D-2249

THOROUGH, RESPONSIBLE, EFFICIENT YOUNG MAN, 37, desires position as asst exec. Experienced chiefly in design and devpmt work, util and industrial. Experience includes maintenance, estimates, valuations and mgmt. Syracuse grad E.E-M.E. 1919. Pleasing personality and mature judgment. B-5505

E.E., 35, 10 yrs experience covering design, cost estimating and equip specifications of pwr plants, industrial bldgs, copper and oil refineries, substations and transmission lines. Also about 1 yr asst research engr with cable co. and 1 yr as tester with elevator co. Licensed N. J. engr. English and German languages. C-5473

UTILITY ENGR, 31, 10 yrs util experience principally with client cos of Elec Bond and Share, includes design, constr and operation of transmission and distribution systems, investigations and economic studies, networks, reconstruction and development planning, annual budgets, acctg. and genl engg work affecting more economical operation and maintenance of facilities. B-6934

B.S. in E.E. 1920; Univ. of Pa, 38, married. One yr spl. test, elec pwr, lt co; 13 yrs engg dept Bell System. Interested in refrigerating and air conditioning. Desires exec position in either elec or mech field. Available short notice. Location East. D-2299

YOUNG ELEC ENGR, formerly examining officer and inspector in charge of field office of radio division of dept of Commerce and Federal Radio Commission, desires to prove his value to an organization engaged in electronic endeavor, viz.—radio, television, sound motion pictures, etc. Dependable character, references from persons of repute available. D-1804

ENGR, 30, 1½ yrs engg and estimating constr of telephone aerial and underground plant; 5½ yrs cost analysis, complex special studies, forecast-

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

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ing market and financial requirements of plant dept, preparation of rate case data. 1 yr personnel administration. 1 yr responsible independent field representative for util commission. Available immediately. D-2345

AVAILABLE, mech and elec engr; 43, with 22 yrs experience from machine shop to chief engr of large elec machy mfr. Able exec with initiative inventive ability and good personality. Can take care any mech devpmt work from shop to customer, assisting sales dept when required. First-class references furnished. A-445

A.B. with 2 yrs subsequent education in E.E.; 2½ yrs secondary school teaching; 1½ yrs Westinghouse engg app; 2½ yrs illumination design, pwr plant inspection, etc, for the Philippine Govt; 16 yrs long distance telephone cable and cost studies, correspondence. D-2342

ENGR AND EXEC, married, grad E.E.; experienced in util and mfg fields, transmission and distr. Fourteen yrs with large util and 7 yrs with mfr of elec equip. Particularly interested in rehabilitation work, valuation, economy of operation and devpmt. D-2358

Instruction

B.S. and E.E., Mich. State Col., 31, G.E. test, 4 yr. practical experience with (manual, supervisory, controlled and automatic pwr substations, automatic ry substations (rotary converter and rectifier) and frame mounted, cell mounted, and metal clad) equipment. Willing to do engg, operating or teaching. D-1597

ELEC-MECH engr, 35, Tau Beta Pi; 10 yrs teaching; 5 yrs engg faculty Cornell Univ.; 4 yrs mfg engr; 1 yr elec designer Stone & Webster; cons E.E., constr Boston Traffic Tunnel. Now teaching, minor technical institution. Wants position teaching in coll or engr industrial or constr co. C-5876

TEACHER of E.E., 34 B.S. in E.E. and E.E. deg. Testing experience, col teaching experience, 5 yrs head of tech section of large engg and constrn. co, 2 yrs head of tech section of large operating co. Desires teaching position in col or univ. D-2344

Junior Engineers

JUNIOR ENGR-ELEC; 25, married, experienced in drafting, assessment, tabulation, inspection and in util research. Also interested in illumination and electronic applications. Available on 2 wks notice. Location immaterial. Desires permanent connection with a reliable co. D-1041

B.S. in E. and E.E. 1933, single, good health and industrious and willing to do any kind of work. Some experience in wiring and repair. Location immaterial. D-2241

E.E. for util, 26, Sc.M., M.I.T. '33, specializing transmission, distribution, util economics. Phi Kappa Phi. Three yrs testing, switchgear engg experience, G.E. Co. on devpmt, application and specifications. Considerable experience report writing. Prepared for protective engg, distribution systems, planning, economic studies. Available October 1. Eastern locality preferred. D-560

DR. ENGG, J.H.U. '33, 25, single, Tau Beta Pi, Sigma Xi. Research experience in elec measurements. Intimate knowledge of a-c bridges and dielectric loss measurements. Desires research position or instructorship in E.E. Will also consider any engg position. Location immaterial; available immediately. D-2301

B.S. in E.E., communications; Univ. of Calif., 1933, 24, married. Desires connection with firm producing equipment using grid glow tubes and photoelec cells. Available now at any location, any living salary. D-2228

B.S. E.E., 1933, N. C. State, single, 19, honor student, Tau Beta Pi, Phi Kappa Phi. Specialized in communications. Experience in amateur radio, radio repair, radio experimentation. Can type. Good at lab work. Prefer research or devpmt, will take anything elec. Excellent references. Available immediately. Location immaterial. Salary secondary. D-2314

E.E. GRAD, 1933, R.P.I., 22, single. Experience in pwr engg; character of work and location immaterial. Available immediately. D-2313

E.E. Cornell, 1933, 21, single. Held several scholarships and earned large percentage of col expenses. Member of several social and musical clubs. Considerable sales experience during summers. Interested primarily in engg sales work. Prefer N. Y. State location. Would call for interview immediately anywhere in state. References available. D-2311

GRAD E.E., 25, single, special study in util economics and mgmt at 2 leading univ. Two yrs varied experience in util. Valuable training and aptitude for pub relations work in a util. Opportunity to work into administrative dept paramount to salary. East preferred. C-9957

B.S. in E.E., Lewis Inst, 1933 grad, 23, single. Any engg job will be acceptable and good col references can be furnished on request. Scholastic record is excellent. D-2312

PURDUE GRAD, 1929, B.S. of E.E., 26, single. Six mos with radio mfr, 1 yr extensive util training course, six mos in engg office. References. Desires employment with util or mfr. D-1801

B.S. in E.E. '33, Univ of Ark., chairman Student Branch A.I.E.E., president Tau Beta Pi, honor grad. Experienced in acctg and clerical work. Desires any type engg work. Salary secondary, location immaterial. Good references. D-2332

B.E.E. cum laude, P.I.B., 1933, 20, mathematically inclined. Desires position in E.E. field, preferably in communications. D-2298

JUNIOR ENGR. Light or heavy traction field is especially desired. B.S. in E.E., 1933, New York Univ, 21, single. Has also had training in the radio field. Desires position in any elec field. Location and salary secondary. Available at once. D-2261

B.S. in E.E., 1931 grad, single, 25, desires position in E.E., preferably teaching or research. Two summers' experience with elec contracting co. References. Salary and location secondary. Available immediately. D-1259.

E.E. grad of '33 desires work as laborer or as a professional in the elec industry with chances for advancement. No practical experience. Majored in pwr engg with illumination minor. Will go anywhere. D-2335

B.S. in E.E., 1933, Drexel Inst, 23, single. Six mos experience with G.E. Co., and experience with shipbuilding co. Interested in transmission and distribution and desires position with util or mfg co. Available immediately. Eastern states preferred. D-2334.

B.S. in E.E., 1933, Univ of Ill., 23, married. Desires E.E. work of any type with a future. Location immaterial. Available immediately. D-2343

B.S. in E.E., Milwaukee Sch of Engg. Especially interested in research, but willing to work in any capacity. Experience in radio servicing. Location and salary immaterial. Available at once. D-2341

B.S. in E.E. and M.E., Univ. of Calif. 1933. Member of Sigma Xi, Tau Beta Pi and Eta Kappa Nu, 24, single. Specialized in pwr work. Desires any type of engg work. Location immaterial. Available at once. D-2357

Maintenance and Operation

E.E. GRAD, 1928, 35, single. Desires position with operating or constr concern. Six yrs pwr plant experience, hydro and steam. Operation, maintenance, test, inspection, constr, engg and instruction. Also has 5 yrs acctg experience. Location immaterial. C-7796

E.E., 38, grad E.E., McGill. Extensive experience charge design, constr, operation, maintenance plant and substations, transmission, trolley and telephone lines; maintenance elec rolling stock, steam train ltg and elec drive and ltg equip, factories, shops, offices, etc. Record rapid advancement. Good organizer. Speaks Spanish. School grounding in French. C-9557

GRAD E.E. with 4¾ yrs experience in elec engr's office of large eastern RR on drafting and pwr plant design and the field investigation of requisitions for new elec and pwr plant equip. Four and one-half yrs experience as electrician on Diesel, Diesel-elec and turboelec freight and passenger ships. C-8160

Research

M.S. in E.E., Columbia, 28, single. Five yrs experience in analysis and test of local telephone circuits and apparatus. Interested in applied electromagnetic or electronic devpmt and research. D-2227

B.S. (in biology), B.S. in E.E., 1 yr grad work, 29, married. One yr as student engr and 2 yrs as research and devpmt engr with an elec mfg co. Practical experience with small motors, thermionic tubes, and ventilating and air conditioning equip. Location immaterial. Available immediately. D-2300

GRAD ENGR and physicist, 34, vacuum tube and high frequency experience, competent to develop new devices, or at lab measurements. Available at once, anywhere, salary low. B-8390

Sales

E.E. GRAD, 28, single. Three yrs sales experience of elec equip in Southeast. Also mfg and erection experience while student. Consider any location in U.S. D-629-4687-Chicago.

SALESMAN, Bliss grad, 31, single, 6 yrs sales engr instruments. Called on industries, central stations and RR in N. Y. City, N. Y. State, N. J. and Conn. Good sales record. No particular line desired. C-1570

Membership

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before August 31, 1933, or October 31, 1933, if the applicant resides outside of the United States or Canada.

Anctil, A. E., Shawinigan Water & Power Co., Thetford Mines, Quebec, Can.
Duncan, V. G., P. O. Box 124, Fortress Monroe, Va.
Flye, H. W., Alum. Co. of Am., San Francisco, Calif.
Friedman, J. W., Electime Corp., Bklyn., N. Y.
Fuller, M. A., New Mexico Properties, Texas La. Pwr. Co., Silver City, N. M.
Hawley, H. A., Am. Tel. & Tel. Co., N. Y. City.
Heckel, G. M., 92–43 52nd Ave., Elmhurst, L. I., N. Y.
Holden, W. H. T. (Member), Am. Tel. & Tel. Co., N. Y. City.
Lowe, H. F., Sloan & Cook, Chicago, Ill.
Marcovitch, H. B., 1714 McGowen Ave., Houston, Texas.
Matjasich, F. J., Golden State Co., Ltd., San Francisco, Calif.
McCune, F. K., Gen. Elec. Co., Lynn, Mass.
Rollinson, J. W. (Member), Industrial Elec. Co., Savannah, Ga.
Sloan, W. F. (Member), Sloan & Cook, Chicago, Ill.

Wood, W. R., United Fruit Co., N. Y. City.
15 Domestic

Foreign

Castillo y Bravo, M., 11a, la Rosa, No. 282, Mexico City, Mexico.
Chan, G. S., 28 Chuen Yuen, Tung Shan, Canton, China.
Durling, F. A., 109 Central Ave., Panama, Rep. of Panama, C. A.
Dutt, J. B., Jhansi Elec. Supply, Jhansi, U. P., India.
Hunter, P. V. (Fellow), Callender's Cable & Constr. Co. Ltd., London, E. C. 4, Eng.
5 Foreign

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the address as it now appears on the Institute records. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Collins, H. Stanley, 100 Carlson Road, Rochester, N. Y.
Durant, Wm. T., 736 Broadway Ave., Regina, Sask., Can.
Hottle, Warren M., 437 Hansberry St., Phila., Pa.
Ingles, J. A., c/o Trans. Dept., H. E. P. C., MacLean Bldg., Toronto, Ont., Can.
Jones, Edgar A., 2590—35th St., Astoria, L. I., N. Y.
Kresser, Jeav V., 1106 Bush St., Apt. 407, San Francisco, Calif.
Kubota, K., c/o Japanese Assn. of N. Y., 1819 Broadway, New York City.
Montgomery, M., Stock Exchange Bldg., Vancouver, B. C., Can.
Moore, Everett, 2479 Kalakawa Ave., Honolulu, T. H.
Nelson, Forrest S., 63 Boyd St., Worcester, Mass.
Parker, Ray H., 5355 Poinsette Ave., Richmond, Calif.
Pedersen, P. R., c/o Sanderson & Porter, 52 William St., New York City.
Perkins, T. S., 154 Maple St., Springfield, Mass.
Stewart, Jenner M., Gen. Del., Jackson, Miss.
Walters, Louis, G., c/o Y. M. C. A., Portland, Ore.

Engineering Literature

New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, during June are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface or text of the book in question.

FAN ENGINEERING. Edit. by R. D. Madison and W. H. Carrier. 3 ed. Buffalo, Buffalo Forge Co., 1933. 622 p., illus., 7x4 in., lea., $3.00.—A convenient collection of numerical and technical data frequently wanted by users of fans. Part one discusses the general physics of air and the matter of air flow. Part two deals with the uses of fans for air conditioning, heating, drying, combustion, dust removal and other industrial purposes. The final section discusses the selection of fans and gives performance tables, dimensions and other information concerning the products of the publisher.

GENERAL PROPERTIES of MATTER. By F. H. Newman and V. H. L. Searle. 2 ed. N. Y., Macmillan Co., 1933. 388 p., illus., 9x6 in., cloth, $4.00.—Aims to present a fairly complete survey of the fundamental properties of matter, especially developing those branches of the subject, such as surface tension, osmosis and viscosity which verge toward chemistry, and hydrodynamics and vibrations, which are more particularly of importance to the mathematician and engineer. The authors explain the necessary mathematics but assume a knowledge of the calculus.

INDEX to the LITERATURE of FOOD INVESTIGATION, v. 4, No. 2, Sept. 1932. Lond., Dept. of Scientific and Industrial Research, 1933. 182 p., 10x6 in., paper, 2s 6d. (British Library of Information, N. Y.).—Covers thoroughly the recent literature upon the preservation and transport of food, including much of interest to engineers upon canning, temperature and humidity control, transport by sea, rail and road, heat insulation, refrigerating machinery, and air conditioning. Over 90 periodicals are indexed and the entries are annotated.

INTERNATIONAL CRITICAL TABLES of NUMERICAL DATA, PHYSICS, CHEMISTRY, and TECHNOLOGY. INDEX, v. 1–7. Ed. by Nat. Research Council. N. Y. and Lond., McGraw-Hill Book Co., 1933. 321 p., 11x9 in., cloth, $6.00. Here are listed alphabetically the chemical compounds and systems, industrially important materials, minerals and rocks, the names of effects and formulas, and such general properties of materials as boiling points, refractive indices, etc., with references to the proper table. Owners of the tables will find the new volume indispensable.

KÄLTEPROZESSE. By P. Ostertag. 2 ed. Berlin, J. Springer, 1935. 112 p., illus., 10x6 in., cloth, 8.80 rm. By using the entropy diagram the author is able to solve the problems of the designer of refrigerating plants with clearness and simplicity. Illustrated by numerous examples. Special attention is given to multi-stage compressors and turbo-compressors. The book also contains entropy diagrams for ammonia, carbon dioxide, sulphur dioxide, and ethyl bromide, as well as Mollier diagrams for first 2 of these.

NETWORK SYNTHESIS. By Ch. M: son Gewertz. Baltimore, Williams & Wilkins Co., 1933. 237 p., diagrs., 10x6 in., cloth, $4.00.—This is, according to its author, the first published work upon network synthesis. It presents a complete treatment of 4-terminal network synthesis from prescribed driving-point and transfer functions, and in addition a theory of functions of a complex variable and matrix necessary for network synthesis in general.

PHYSIOLOGICAL EFFECTS of RADIANT ENERGY. (American Chemical Society Monograph No. 62). By H. Laurens. N. Y., Chem. Cat. Co., 1933, 610 p., illus., 10x6 in., cloth, $6.00.—Dr. Laurens's monograph provides a comprehensive summary of our knowledge of the effects of sunlight and other forms of radiant energy upon life, which can be used as a source book by all who are interested in the subject. The information assembled will be of use to engineers and physicists concerned with artificial sources of radiant energy and the behavior of various glasses, as well as to physicians. An extensive bibliography is included.

POPULATION TRENDS in the UNITED STATES. By W. S. Thompson and P. K. Whelpton. N. Y. and Lond., McGraw-Hill Book Co., 1933. 415 p., illus., 10x6 in., cloth, $4.00.—In gathering the information on population for the President's research committee on social trends extensive compilations were accumulated which could not be included in the committee report. These longer tables are presented here and their significance discussed in greater detail.

PUBLIC UTILITY RATE STRUCTURES. By L. R. Nash. N. Y. and Lond., McGraw-Hill Book Co., 1933. 379 p., illus., 9x6 in., cloth, $4.00.—A compilation of technical, as distinct from legal, information about rate practices and applications. Such topics as rate reduction, promotional rates, regulation of rates *versus* regulation of profits, cost analyses and economic factors are discussed, and references provided for further reading. The distinctive features of the rate structures used by electric, gas, local transportation, communication, water, and street lighting services are considered.

STANDARD COSTS. By H. E. Kearsey. Lond., Sir Isaac Pitman & Sons, Ltd., 1933. 177 p., illus., 9x6 in., cloth, $2.25.—The subject of costing is discussed in a broad way, without reference to specific industries. The purpose is to explain and illustrate modern tendencies, to emphasize the need for scientific method and to point out advantages to executives who are not conversant with standard costing.

STARKSTROMMESSTECHNIK. By G. Brion and V. Vieweg. Berlin, J. Springer, 1933. 458 p., illus., 10x7 in., cloth, 37.50 rm. This book is designed for use in power plants and factory test floors where heavy-current measurements are made, and is intended as a comprehensive manual of reference. All the usual measurements are included. References to the literature are numerous. brief bibliographies are added to each section and an index is provided.

TECHNICAL MAN SELLS HIS SERVICES. By E. Hurst. N. Y. and Lond., McGraw-Hill Book Co., 1933. 239 p., 8x6 in., cloth, $2.00.—The purpose of this book is to help the technical man find a job. The author writes from extensive experience in helping college graduates to find positions, which experience he here condenses into a series of typical cases that illustrate the methods advocated.

THEORY of THERMIONIC VACUUM TUBES. By E. L. Chaffee. N. Y. and Lond., McGraw-Hill Book Co., 1933. 652 p., illus., 9x6 in., cloth, $6.00. A comprehensive theoretical treatment of the fundamentals of thermionic emission and of the vacuum tube, covering in detail the general properties of the tube and its use as an amplifier and detector. Limited to vacuum-tube operation at low power.

ROYAL TECHNICAL COLLEGE JOURNAL, v. 3, pt. 1, Jan., 1933. Glasgow, 199 p., illus., 10x7 in., paper, 10s 6d. This volume records some of the research work done at the College during the past year, chiefly in physics, chemistry, and engineering. Among the papers are investigations of the measurement of peak voltages, power-factor improvement for industrial loads.

STANDARD WIRING for Electric Light and Power. By H. C. Cushing, Jr. 39th ed. New Rochelle, N. Y., H. C. Cushing, Jr., 1933. 456 p., illus., 7x4 in., lea., $3.00. This work presents the essential requirements for proper wiring for light, heat, and power, with explanations of engineering practice, tables, illustrations, etc. It is intended to give workmen the information necessary to insure installations complying with the National Electric Code. This edition, in addition to careful revision, has new sections on farm wiring and on the measurement of insulation and ground resistance.

TELEVISION. By K. A. Hathaway. Chicago, Am. Tech. Soc., 1933. 169 p., illus., 9x6 in., cloth, $2.00. An elementary, non-mathematical presentation of the subject, with emphasis upon the principles involved. Much space is given to scanning devices and systems, especially mechanical systems.

TRAVELING WAVES on TRANSMISSION SYSTEMS. By L. V. Bewley. N. Y., John Wiley & Sons, 1933. 334 p., illus., 9x6 in., cloth, $4.50. Aims to present a fundamental, generalized mathematical analysis of the subject which will have permanent reference value and thus be useful to practicing engineers as well as students. Part 1 discusses the origin, characteristics, and behavior of traveling waves; part 2, high-frequency oscillations and terminal transients of transformers. Selected bibliographies accompany each section.

VERHALTEN KERAMISCHER WERKSTOFFE bei ZUGDRUCK-DAUERBEANSPRUCHUNG. By F. Heumann. Berlin, VDI-Verlag, 1933. 42 p. illus., diagrs., charts, tables, 8x6 in., paper, 4.50 rm. An investigation of the failure of porcelain insulators, specifically to determine whether porcelain, like metals, experiences fatigue. Endurance tests upon a number of different porcelains are described in detail. They show that porcelain experiences fatigue, but not enough to cause failure of insulators.

VIERSTELLIGE TAFELN der KREIS- und HYPERBELFUNKTIONEN, sowie IHRER UMKEHRFUNKTIONEN im KOMPLEXEN. By R. Hawelka. Braunschweig, F. Vieweg & Sohn Akt.-Ges., 1931. 93 p., illus., 12x8 in., 10 rm. These tables have been prepared to expedite the computation of a-c problems, and are sponsored by the German Society of Electrical Engineers. Values for the 4 circular functions and the 4 hyperbolic functions are given. An introduction, in English, explains the computation and use of the tables.

Engineering Societies Library

29 West 39th Street, New York, N.Y.

MAINTAINED as a public reference library of engineering and the allied sciences, this library is a cooperative activity of the national societies of civil, electrical, mechanical, and mining engineers.

Resources of the library are available also to those unable to visit it in person. Lists of references, copies or translation of articles, and similar assistance may be obtained upon written application, subject only to charges sufficient to cover the cost of the work required.

A collection of modern technical books is available to any member residing in North America at a rental rate of five cents per day per volume, plus transportation charges.

Many other services are obtainable and an inquiry to the director of the library will bring information concerning them.

Industrial Notes

General Electric Orders Show Slight Gain.—Orders received by the General Electric Company in the second quarter of 1933, announced by President Gerard Swope, amounted to $35,539,858, compared with $35,304,070 in the corresponding quarter last year, an increase of about 1 per cent. Orders for the first six months of 1933 amounted to $61,051,502, compared with $68,708,712 for the first half of 1932, a decrease of 11 per cent. Sales billed for the first six months of 1933 amounted to $61,773,414.19, compared with $80,219,489.15 for the corresponding period last year, a decrease of 23 per cent.

G & W Appoints New York Representative.—C. M. Converse and L. V. Jochum have been appointed by the G & W Electric Specialty Co., Chicago, manufacturer of cable terminal devices, as New York representatives, with offices at 30 Church St., and succeeding Raymond Roth, Inc.

Ohio Brass Elects George L. Draffan.—At a recent meeting of the board of directors of the Ohio Brass Co., Mansfield, O., George L. Draffan was elected vice-president of the company and its subsidiaries. Mr. Draffan has been associated with the company for the past seventeen years. In 1930 he was appointed secretary and director of sales after having held the position of general sales manager for several years.

New Testing Set.—A portable, multi-range a-c test set has just been introduced by Ferranti, Inc., New York. The instrument consists of two $2^1/_2$ in. dial, $2^1/_2$ in. scale moving iron movements fitted in a compact, highly finished black molded case with hinged lids. The voltmeter has six ranges, namely, 0/7.5/15/30/150/300/600 volts. The ammeter has two scales of 0/0.5 and 5 amperes. The set is suitable for use on frequencies of from 25 to 100 cycles and may be used on direct current with only a slightly reduced accuracy. This instrument has many uses around the central station or industrial plant. It affords a quick and accurate means of checking voltage and current on motors, transformers, etc., and has the added advantage that it may be carried in the pocket.

Ladder Truck.—A new, general purpose ladder truck, manufactured by the American Coach & Body Co., 3809 Clark Ave., Cleveland, O., is stated to have unusual convenience and safety features which are expected to commend it to public utility companies, to municipalities for servicing street lamps, to telegraph and telephone companies for overhead splicing work, and to railroads for the upkeep of their communication systems. It is also adapted for tree-trimming. The ladder, which is extensible up to 25 feet, may be directed forward over the driver's cab or at either side of the truck without additional support. Since these latter positions give an overhand up to 11 feet, it is easily possible to reach street lamps, etc., even over parked cars in congested areas, especially as a toothed rack within the truck body permits eight different adjustments of ladder angle. To take care of the severe stress involved, the interlocking rails of the ladder are designed so as to provide unusual trussing support. The upper section of the extension ladder carries a hinged platform with a two-section guard rail which fully encloses the workman. Special safety features are also included to protect him from accidental grounds through contact with high voltage wires. The guard rail is thoroughly insulated and all ladder rungs are knurled and covered with a thick layer of molded-on rubber. When not in use the two ladder sections are telescoped together on a light carrier frame above the body.

New Weld Timer.—The Electric Controller & Mfg. Co., 2690 E. 79th St., Cleveland, O., announces a recent development in the EC&M automatic weld timer. This timer does not provide a definite amount of time for each weld, but varies the time automatically in inverse proportion to the rate of current flow to produce a 100% weld at each operation. Previously, the many variables entering into the welding circuit have made it difficult to secure welds of identical uniformity even with a careful and skilled operator working under the most favorable conditions. When installed and adjusted for the range of work at hand, it is claimed that with this new device each weld will be perfect and all welds will be uniform regardless of fluctuations in line voltage, condition of electrodes, variations in thickness of material, amount of rust, dirt, scale, etc. Reports from companies using this timer who have tested welds secured on ordinary black sheets indicate that, in many cases, they can greatly reduce their cost of production by using these sheets in place of the more expensively finished sheets. The original adjustment of the timer is easily made by welding a few scrap pieces of the work to be done and then these welds are torn apart for inspection. When the desired weld is obtained, the cabinet door of the timer may be locked and for all practical purposes within reasonable limitations, it will not be necessary to readjust the timer; the first weld obtained being identically the same as the last one at the end of the day's run. For the exceptional case, however, the adjusting dial on the weld timer can be changed to suit the particular condition.

Trade Literature

Motor-Starting Switches.—Bulletin GEA-1761, 4 pp. Describes type CR1061, small, hand operated starting switch for fractional horsepower motors. It provides complete protection against stalled-rotor current and injurious overload conditions. General Electric Co., Schenectady, N. Y.

Instrument Transformers.—Catalog 45, 64 pp. Technical data, ratio and phase angle curves, descriptive information, and prices are included. Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

Gear-Motors.—Bulletin GEA-1765, 4 pp. Describes fractional horsepower gear-motors, $^1/_6$ to $^3/_4$ horsepower, 500 to 11 rpm, single phase, polyphase or direct-current. General Electric Co., Schenectady, N. Y.

Split-Phase Motors.—Bulletin 167, Part 5A, 6 pp. Describes Wagner split-phase motors. Illustrations of motor parts are surrounded by paragraphs defining functions and construction. Wagner Electric Corp., 6401 Plymouth Ave., St. Louis, Mo.

Bakelite.—Booklet, 16 pp. The pamphlet sketches briefly the origin, manufacture and industrial applications of many types of Bakelite products made from the initial resinoid. Bakelite Corp,. Bound Brook, N. J.

Photoelectric Relay.—Bulletin GEA-1755 4 pp. Describes type CR 7505-K1 photoelectric relay, suitable for simpler applications wherein the operating light beam is completely intercepted by an object which is practically opaque. General Electric Co., Schenectady, N. Y.

Split-Core Transformer Test Set.—Advance Price Sheet 3 for catalog 123. Describes a new test set consisting of the type CSO split-core transformer with either a type PA or type Steel-Six portable ammeter. With this new test set it is possible to obtain alternating current ampere readings as low as $^1/_2$ ampere and as high as 200 amperes. Roller-Smith Co., 12 Park Place, New York.

Vitrohm Rheostats.—Bulletins 1103–1104–1105. Describe Vitrohm coil type rheostats, with fine continuous adjustment, especially suitable for fractional horsepower motor control, filament control, etc., where space is limited. **Resistors.**—Bulletins 11–19–25, describe Vitrohm (vitreous enameled) resistors, mountings and enclosures. Ward Leonard Electric Co., Mt. Vernon, N. Y.

Prepayment Meters.—Bulletin 82, 4 pp. Describes type HCP prepayment meters, which are built in all single phase capacities from 5 ampere to 25 ampere inclusive, both two-wire and three-wire. The coin mechanism is arranged for the U.S. quarter. By appropriate gear change wheels, any kilowatt hour rate from three cents to fifteen cents, varying by one-half cent steps, can be secured. The total of the money inserted, the unused kilowatt hours and the total kilowatt hours used are all registered on appropriate indicating circles. The meter element consists of the standard Sangamo type HC watthour meter, while the coin mechanism is the same as that used abroad in the product of the British Sangamo Company, Ltd. Summer or winter resorts, tourist camps, athletic fields, special apartments or residences where the length of occupancy is limited, or where accounts are delinquent, are a few of the representative installations where this type of meter can be used to advantage. Sangamo Electric Co., Springfield, Ill.